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Fifth Annual Report

of the

Board of Harbor Commissioners.

JANUARY, 1871.

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FIFTH ANNUAL REPORT

OF THE

Massachusetts.

BOARD OF HARBOR COMMISSIONERS.

JANUARY, 1871.

BOSTON:
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Commonwealth of Massachusetts.

REPORT.

To the Honorable Senate and House of Representatives of the Commonwealth of Massachusetts:

The Board of Harbor Commissioners respectfully submit their Fifth Annual Report.

South Boston Flats.

On the 21st day of June, 1869, this Board, with the approval of the governor and council, sold to Messrs. Harvey, Whitney and Groves, trustees of the Boston, Hartford and Erie Railroad Company, 1,091,010 square feet of the State flats in South Boston, represented on the annexed plan by so much of the area colored green as lies north-easterly of the line X Z, for the note of the company for $545,505, payable in twenty years and secured by a mortgage on the flats conveyed, subject to no other incumbrance. The residue of the area colored green, consisting of flats on the north-easterly side of Commissioners' line A and filled land on the south-westerly side of this line, the Boston, Hartford and Erie Railroad Company, through its trustees, had purchased of the Boston Wharf Company for $1,350,000, payable in bonds on twenty years' time with interest, at seven per cent., to the amount of $1,200,000, and a note for $150,000 at the same rate of interest, payable in three years, secured respectively by mortgages back to Messrs. Pierce, Atkins and Morton, its trustees, and to the company. The mortgage to the Commonwealth covers, besides the tract granted by it, the tract pur-

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chased by the trustees of the Boston, Hartford and Erie Railroad Company of the Boston Wharf Company, subject, however, to the two mortgages already mentioned, amounting in the aggregate to $1,350,000. All these mortgages, the Commonwealth's and those of the Boston Wharf Company and its trustees, contain powers of sale and authorize the mortgagees and their assigns to purchase at the sales made under those powers. In order, however, to enable the legislature to have an opportunity to exercise the State's rights as a subsequent mortgagee and protect its interests, the Boston Wharf Company and its trustees bound themselves to give the State nine months' notice of any such sales under their mortgages.

The conditions of the mortgage to the Commonwealth provide not only for the payment of the note of the Hartford and Erie Railroad Company for the purchase money for the flats sold to it, but also for the construction, on the border of all its flats on Fort Point Channel and the Main channel, of a sea-wall and the filling of these flats under the direction of the Harbor Commissioners, in accordance with the terms of the company's contract with the Commonwealth. This work was to be completed within three years from the date of the contract (June 21st, 1869).

On the 8th day of December, 1869, this Board, with the executive approval, entered into an agreement with the Boston and Albany Railroad Company to convey to it fifty acres of South Boston flats adjoining those of the Boston, Hartford and Erie Railroad Company for $435,600, payable in three years from October 1st, 1869. The company binds itself to fill these flats under the direction of this Board, and build in a specified manner a sea-wall on the line of these flats bordering on the Main channel, within six years, and is obliged to finish this work to entitle it to a conveyance.

Copies of the written instruments by which these transactions were consummated are appended to the report of this Board to the legislature of 1870, and reference is made to that report for more detailed information. Without making the contract of the Boston and Albany Railroad Company dependent at all upon the execution of that of the Boston, Hartford and Erie Railroad Company, it was the intention that each corporation should have three years in which to do its work, even if nothing was

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done by the Boston and Albany Railroad Company before the work of the Boston, Hartford and Erie Railroad Company was completed.

The Boston, Hartford and Erie Railroad Company entered upon its work. It constructed on the south-easterly line of its flats an extensive bulkhead with a wing running westerly at right angles with this line, designed for the protection of the filling from the action of the currents; it partially excavated the trenches for the foundation of the sea-walls, and drove for about 410 feet the piles on which the base of the lighter of its walls was to rest, and partially built a detached section of the wall itself. In this work and in gravel filling inside of Commissioners' line A, the company expended, it is alleged, about $100,000. This was all done in the latter part of the year 1869, and before our report for that year was submitted to the legislature. The insolvency of the company stopped the work, and nothing further has been done.

The present general condition of the territory and the structures mentioned is what might be expected to result from the suspension of the work. The bulkheads have suffered from the effects of storms and ice. The outer part on the south-easterly line of the tract of the Boston, Hartford and Erie Railroad Company has withstood these adverse influences better than the wing and is in a fair condition, only a small part of the planking having been torn off and the main structure being still firm and in position. The same cannot be said of the wing. More than half of the planking here has been torn off, and the whole structure is much dilapidated. At present it could serve but imperfectly the purpose of a temporary retaining wall. The material deposited by the Boston, Hartford and Erie Railroad Company within the inclosure of these bulkheads (amounting to about 30,000 cubic yards dredged from the trenches) has been washed down to a generally smooth surface, the highest part not being more than a foot or a foot and a half above the previous level of the flats. This indicates that the materialis of a kind easily worked upon by the action of the water, and demonstrates the necessity of its inclosure to keep it from being swept by the currents into the channels and other sections of the harbor. The trenches dredged out for the sea-walls by the Boston, Hartford and Erie Railroad Company have

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partially filled up again by the natural action of the water. In December, 1869, the trench for the heavy sea-wall was 400 feet long, 50 feet wide, had an average depth of 9 feet, and contained 6,667 cubic yards. A recent survey shows the trench to be 400 feet long, 40 feet wide, and on an average 8 feet deep, and to contain but 4,741 cubic yards, leaving a difference of 1,926 cubic yards, which represents the extent to which the trench has filled up since it was dug.

The trench for the light sea-wall along Fort Point Channel, in 1869 was 1,700 feet long, 15 feet wide, and on an average 4½ feet deep, and contained 4,250 cubic yards. The recent survey of this work before mentioned shows a length of 1,550 (the residue having been filled up with wall and piles for the foundation of the wall), a width of 15 feet, and a depth of 3½ feet, equal to 3,014 cubic yards. This shows a large filling, after allowing for the section occupied by the piles and wall.

Resumption of the Work.

The interests of the Commonwealth require that the work upon these flats should be resumed at the earliest moment practicable, and vigorously prosecuted. The occupation of the flats of the Boston, Hartford and Erie Railroad Company is a very desirable preliminary to the occupation of the flats sold to the Boston and Albany Railroad Company and of those of the State beyond; certainly a necessary preliminary to such occupation upon the plan that is best for the harbor and requires the least outlay in the construction of temporary retaining walls or bulkheads. Delay here tends to delay the whole improvement and to postpone the benefits that the State is to derive from it. What has been done so far has merely created dangerous obstructions in the pathways of vessels which will become more and more annoying and injurious, unless soon put to use in the resumed work of reclamation. Moreover, these fragments of work, which cost a considerable outlay and which will soon become worthless if abandoned, can, at a small expense, be made as serviceable as ever for the purposes for which they were intended. As the work, however, that has been done, excepting a portion of the trenches and a few piles driven to mark the line of the wall, has been done on the tract mortgaged to the trustees of the Boston Wharf Company, it can be made of service to the Common-

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wealth only in the case of the redemption of the mortgages prior to its own, upon these flats.

Two courses to an early resumption of this work are open to the Commonwealth. It can foreclose its own mortgage by the execution of its power of sale, purchase the property at the sale and redeem these mortgages held by the Boston Wharf Company and its trustees, amounting to $1,350,000 and the accrued interest, and itself do the work of reclamation at a cost for filling and walls, reckoned roughly on the basis of former estimates, of about $1,500,000 more, and after the completion of the work, sell the territory thus acquired and reclaimed at its value in the market.

The area of this territory would be about three and a quarter millions of square feet. This would cost the State the amount of the two mortgages and the accrued interest, say $1,450,000, and the expense of the sea-walls and filling, estimated at $1,500,000 more, making a total cost of $2,950,000. It would not generally be denied that the average market value of the whole tract after the reclamation and the establishment of connection with the city proper at the foot of Summer Street, by the construction of Eastern Avenue over Fort Point Channel, would not fall short of a dollar a square foot. Yet, upon this basis, a margin of profit would be left for the State. A dollar a foot, however, would probably, in the opinion of many persons of sound judgment in such matters, be regarded as too low an average for the price this property would bring on the conditions supposed. It is proper to assume that the estimated outlay substantially covers the cost of constructing Eastern Avenue over Fort Point Channel, as the mortgage for $150,000 made by the Boston, Hartford and Erie Railroad Company was given merely as security for the construction of this bridge. An agreement was given by the Boston Wharf Company that this mortgage debt should be deemed satisfied and paid on the establishment of this connection with the city proper.

On the other hand it may be said, that while the outlay is certain and the ever accumulating interest account inevitable, the immediate market value of the result of the work, when accomplished, is at best but a matter of probability. The degree of that probability, different persons will differently

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judge, according to their view of what is demanded by the growth of the city of Boston in the immediate future.

Whether, too, in this matter, the State should assume even the risks that a courageous man of business readily undertakes, will be decided differently by persons according to their view of the appropriate functions of the Commonwealth, and its ability to compete with private enterprise in doing this work at a profit. The Board urge the immediate resumption of the work, whether that resumption shall be undertaken by the Board on the basis of existing laws, which authorize the expenditure of no money from the treasury, or of an appropriation of money for the work, the Board leave to the wisdom of the legislature to determine, submitting such information upon the subject as is in their possession. The relation which the occupation of these flats on Fort Point Channel bears to the whole plan of occupying the State flats in South Boston, amounting to over 700 acres, is such that the prompt accomplishment of the work here is of quite as much importance as the mode of doing it, provided always the State sustain no loss.

The other course to an early resumption of work also requires an execution by the State of its power of sale under its mortgage and a purchase of the property, but instead of a redemption of the mortgages held by the Boston Wharf Company and its trustees, looks to the restoration of the Boston Wharf Company or some other responsible party to the ownership of the property covered by these mortgages, through an execution of powers of sale contained in them, and a purchase of the property either by the Boston Wharf Company or some other solvent purchaser. The coöperation of the owner of this property will be necessary to the State in occupying its own adjacent flats to the best advantage, inasmuch as the flats of the State should be inclosed by a continuation of the wall which must be built along the margin of its neighbor's tract on Fort Point Channel. The Boston Wharf Company's trustees have already made an entry to foreclose their mortgage upon this territory. They could regain their title by executing the power of sale contained in their mortgage after three weeks' notice and buying in the property at the sale. They are restrained from this immediate recovery of their property by the agreement with the Commonwealth to give it nine months' notice of the sale, to

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enable the legislature to have an opportunity to decide whether the State shall exercise its right of redemption. If the State is not to exercise this right, it is for its interest to waive the right to this long notice and permit the Boston Wharf Company and its trustees to make an immediate sale. The sooner the Boston Wharf Company can be invested with the title to the property it sold to the Boston, Hartford and Erie Railroad Company, the sooner the State will have a responsible party ready and anxious to act with it in carrying out this long cherished improvement. With the Boston Wharf Company ready to proceed with the work upon its flats after regaining the title to them, with the Boston and Albany Railroad Company bound to fill fifty acres lying on the south-easterly line of the flats of the Boston Wharf Company and of the State, the Board believe there can be no difficulty in procuring, on sufficiently favorable terms, a contract for the occupation of the twenty-five acres that will belong to the State, forming on the annexed plan the corner between the Main and Fort Point Channels, and so resuming this work during the present year. The Board accordingly recommend the legislature:—

1. To give immediate authority to foreclose the State's mortgage by the execution of its power of sale, and to authorize the purchase of the property covered by the mortgage in the name and behalf of the Commonwealth.

2. To determine whether or not the State will exercise its right of redeeming the mortgages to the Boston Wharf Company and its trustees, with a view to acquiring the whole title to the property covered by these mortgages, and improving this property from its own treasury.

3. To make an appropriation, if this question is decided in the affimative.

4. If this question is decided in the negative, to waive the nine months' notice the Boston Wharf Company and its trustees must now give the State before they can sell under their mortgages.

THE FLATS OF THE BOSTON AND ALBANY RAILROAD COMPANY.

The Boston and Albany Railroad Company has deposited upon its flats about 162,067 cubic yards of material, dredged

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from its docks in East Boston and the harbor near the entrance to them. In accordance with the contract of the company, this is not to be reckoned on account of the thirteen feet to which the flats are to be filled with material dredged from that part of the harbor represented by the area colored red on the annexed plan, but on account of the additional three feet (making a grade of sixteen feet in all), which the company has the right to fill with gravel.

Purchase of South Boston Flats.

The purchase of the tract of flats in South Boston represented in blue on the plan, and situated between B and E Streets, 220 feet distant from the north-easterly line of First Street, has been substantially consummated by the Board, according to the anticipations expressed in its last report. Three undivided eightieths of what is called the "Fan Piece," measuring $163\frac{21}{100}$ feet on First Street, and four undivided sevenths of a parcel measuring 165 feet on the same street are the only interests in that tract that the State has not acquired. The owners of three of these sevenths indicate their willingness to sell on the terms the State has paid to other owners, but too late to complete the transaction before the close of the year when the appropriation expired. The Board therefore request the legislature to renew the appropriation to the amount of twenty thousand dollars, that the whole of this outstanding title may, if possible, be purchased, but certainly the three sevenths whose owners are now ready to sell to the State. The appropriation originally made (chap. 446, Statutes 1869) was $300,000, of which but $229,049.95 has been expended. The area acquired amounts to about 2,159,000 square feet, and by this purchase the State is relieved of any real or imagined obligation to maintain a channel-way in front of the South Boston shore in carrying out its plan for the occupation of its own flats beyond. The area of this channel reservation, 805,000 square feet, should be added to the amount actually purchased to obtain the area the State gains by this transaction for occupation. The State assumes the obligation of reserving from its flats a street fifty feet wide, and of filling it to grade with First Street whenever the whole adjacent area between B and E Streets, 220 feet wide, shall also have been filled to that grade. The riparian

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owners are already taking measures to fill this space. When this is done it will be for the interest of the State to have some portion of these flats it has bought, besides the street, either filled or sold subject to the obligation of building the street. Whichever course shall at the time seem most advantageous to the State, the Board, subject to the approval of the governor and council, will pursue. In order that the Board may contract for or require of a purchaser, filling on the terms obtained by the shore owners, some legislation will be required that will relieve such portion of these purchased flats as are to be filled soon, from some of the provisions of law applicable to section one of the annexed plan.

In making this purchase of flats the following deeds have been approved by the Board and governor and council, and accepted by the Board :—

William H. Story and *al.* to the Commonwealth, dated March 14, 1870. Consideration, $3,300.

Mary Kelly to the Commonwealth, dated August 25, 1870. Consideration, $3,300.

Susanna C. Johnston to the Commonwealth, dated June 8, 1870. Consideration, $3,300.

Osborn Howes *et al.* to the Commonwealth, dated March 23, 1870. Consideration, $15,796.62.

Joseph T. Bailey and *al.* to the Commonwealth, dated March 14, 1870. Consideration, $4,573.24.

Daniel Denny *et ux.* to the Commonwealth, dated March 18, 1870. Consideration, $75,170.

Caleb W. Loring, trustee, to the Commonwealth, dated March 18, 1870. Consideration, $10,391.04.

Caleb W. Loring, guardian, to the Commonwealth, dated June 21, 1870. Consideration, $649.44.

Caleb W. Loring, guardian, to the Commonwealth, dated June 21, 1870. Consideration, $649.44.

Jacob Sleeper and *al.* to the Commonwealth, dated March 1, 1870. Consideration, $17,406.35.

Seth Adams to the Commonwealth, dated March 1, 1870. Consideration, $3,223.40.

William S. Eaton to the Commonwealth, dated March 2, 1870. Consideration, $1,934.04.

Barker B. Kent to the Commonwealth, dated March 1, 1870. Consideration, $17,406.35.

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William B. Dodge to the Commonwealth, dated March 1, 1870. Consideration, $3,223.40.

Samuel S. Perkins to the Commonwealth, dated March 1, 1870. Consideration, $6,446.80.

Frederick Nickerson and *al.* to the Commonwealth, dated March 16, 1870. Consideration, $8,400.

Samuel K. Williams to the Commonwealth, dated March 16, 1870. Consideration, $5,355.

Henry A. Rice and *al.* to the Commonwealth, dated March 18, 1870. Consideration, $1,166.67.

Edward E. Rice and *al.* to the Commonwealth, dated March 18, 1870. Consideration, $1,166.67.

George Woods Rice to the Commonwealth, dated March 16, 1870. Consideration, $1,855.

Henry A. Rice to the Commonwealth, dated March 16, 1870. Consideration, $1,166.67.

Barker B. Kent to the Commonwealth, dated April 20, 1870. Consideration, $8,207.50.

Alpheus Stetson to the Commonwealth, dated March 24, 1870. Consideration, $1.

Alpheus Stetson, guardian, to the Commonwealth, dated April 29, 1870. Consideration, $507.50.

Sarah C. Brooks and *al.* to the Commonwealth, dated March 21, 1870. Consideration, $3,038.67.

William B. Brooks to the Commonwealth, dated March 26, 1870. Consideration, $7.25.

Micajah Pope to the Commonwealth, dated February 28, 1870. Consideration, $15.

Charles B. Bedlington and *al.* to the Commonwealth, dated March 16, 1870. Consideration, $2,677.50.

Charles C. Conley to the Commonwealth, dated March 16, 1870. Consideration, $3,552.50.

The Draws on Charles and Miller's Rivers.

In the early part of the past year the work was finished of building a new draw and widening the draw-way in the Charles River Bridge to the width of forty-four feet. This was done in accordance with the legislation of the year 1869, which required all the draws in the bridges over Charles and Miller's Rivers to be widened to forty-four feet and placed in such position as the Harbor Commissioners should determine, the object being to secure an alignment of the widened passage-ways so that vessels

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might go through them in a straight instead of a zigzag course. The new draw works admirably. It causes a detention of travel of but about seven minutes for every vessel passing through under average conditions. Every expectation the new draw at this point was intended to meet has been fully and satisfactorily answered by the commissioners having charge of the work.

The Fitchburg Railroad Company entered promptly upon the work of widening the draw in its bridge, and only waited for the cessation of navigation in the winter which the construction of the draw would obstruct, to comply fully with the requirements of the law. A renewal of the discussion of this question in the legislature led to still further delay.

The Boston and Maine, Eastern, and Lowell Railroad Companies exerted themselves to secure a large reduction of the width prescribed by the statutes of 1869. All these railroad companies, as also the Fitchburg, had been applicants for the privilege of making extensive encroachments on the flats and water areas of Charles River, already excessively encumbered, and the duty of reconstructing their draws to the width of forty-four feet in proper position was imposed upon them as a compensating benefit to the harbor and to navigation which they ought in fairness to perform. The Fitchburg Railroad Company began at once both to occupy its grants and to widen its draw to the required width. The other companies, having obtained the privileges they had applied for, preferred to concentrate their energies upon securing a reduction to the lowest terms of the obligations imposed upon them, and succeeded in getting a law passed reducing to thirty-eight feet the width of forty-four feet that had been previously prescribed. At this stage of the proceedings the aldermen of the city of Boston, for the first time intervened in their capacity, as they declared, of "surveyors of highways," and the opinion was expressed that the widening of the draw-way of Warren Bridge to thirty-eight feet would involve the removal of the water pipe across Charles River at a cost of $10,000, and that thirty-six feet was in their judgment a sufficient width as a passage-way for vessels. It was perhaps questionable whether the water pipes of the city, or the passage-way for vessels on Charles River, although part of what is called "the highway of nations,"

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were within the jurisdiction of the board of aldermen as surveyors of highways. The opinion too that a width of thirty-six feet would be less of an interference with the water pipe, than thirty-eight feet, proved to be erroneous, and the water pipe to be one not in use. This intervention, however, was the occasion for an attempt still further to reduce the width of the draw-ways, and in the last days of the session a bill was introduced and enacted, requiring not merely the draw in Warren Bridge but all the draws that were to be reconstructed on Charles and Miller's Rivers, ten in number, to be built thirty-six instead of thirty-eight feet wide.

There is a satisfactory ground on which the reduction of the width first established for these draw-ways can be maintained, and the Board are glad to believe it to have been the real one; that ground is the conviction that all these railroad bridges must in a short time be reconstructed or a new way devised for the railroads to cross Charles River that shall be less obstructive to navigation, and injurious to the harbor of Boston, and therefore such temporary provision as can be made to answer the immediate demands of navigation until this radical reform takes place is deemed sufficient. An Act passed by the same legislature that made these successive reductions in the width of the proposed draw-ways, providing that the Railroad and Harbor Commissioners should, if possible, submit to this legislature a comprehensive and feasible plan for improving, at the same time, the navigation of Charles River and the terminal facilities in Boston of the railroads entering the city on the northern side, indicates that such considerations had a controlling influence. Both boards acting together as a joint commission have given this subject a great deal of attention and will submit their results to the legislature in a joint report.

This Board has given the line of the new draw-ways on Charles River to the Fitchburg, Boston and Maine, Eastern, and Lowell Railroad Companies, and approved the respective plans of all except the last, for constructing the draws under the law requiring a width of thirty-six feet. No work, however, has been done upon them since last winter. The construction of the draw of the Fitchburg Railroad Company will temporarily obstruct navigation, and the month of February of this year, this being the month during which there are

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scarcely ever any vessels passing, has been prescribed by the Board as the time for doing this work. The railroad companies whose plans have been approved, have had notice from the joint Commission of Railroad and Harbor Commissioners that plans were entertained by them which, if approved and adopted, would involve further changes in their bridges and draws, and this fact may have led to delay on the part of the railroad companies, that would not otherwise have occurred.

Location of Draw in West Boston Bridge.

Upon the application of the mayors of Boston and Cambridge, who were made by the legislation of last year, *ex officiis*, Commissioners on the West Boston and Cragie Bridges, the Board has revised the location of the draw in the West Boston Bridge made in 1869 and described in its last report. The bridge commissioners represented that the difference in cost that would be made by the change in location, judging from actual proposals received for the work, would amount to twenty thousand dollars, and they wished to avoid so large an expenditure. The reason of the Board for giving the new draw a new location, was the fact that, directly opposite the south-westerly opening of the present draw-way there is quite a serious shoal. A new survey and a comparison of its results and those of the last previous one by the U. S. Commissioners in 1861, showed some changes in this general ground which confirmed the judgment of the Board in their objection to this locality, in its present condition, as a site for the proposed new draw. The shoal has assumed a more abrupt bank on its northern end and has extended northward until it now overlaps the draw-pier, so that within the passage-way and some 80 or 90 feet above the end of the pier there is now but six feet of water where the survey of 1861 gave nine feet. It appeared also that the cost of removing this shoal would not much exceed $5,000, and that once removed it would in all probability either not form again or form very slowly. The Board accordingly, to save expense, revoked the former location and consented that the present location should remain, on condition that the shoal should be first dredged away and that such action should be taken that the depth of the water thus secured should be maintained. It is doubtful whether the bridge commissioners

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have under the statute authority to do this dredging and maintain the depths of water so obtained. That this doubt may be removed the Board desire that the requisite authority should be given by the legislature.

Compensation Assessed for Atlantic Avenue.

After due notice to the city of Boston this Board, on the 29th day of June last, passed a vote requiring the city to pay into the State treasury, in accordance with the provisions of sect. 2, chap. 324, St. 1867, and sect. 4, chap. 149, St. 1866, the sum of $61,663.46 as compensation for tide-water displaced by the construction of Atlantic Avenue. The vote was immediately transmitted through the mayor to the city council of Boston, but no notice has been received by the Board of any action upon it. They learn, however, from the newspapers, that at the close of the last municipal year the city council instructed the mayor to apply to the legislature for relief from this assessment. From the report of the city committee recommending the passage of this order, it appears to have been their impression that since the city was authorized in 1867 to construct Atlantic Avenue, subject to the obligation of making compensation for tide-water displaced by the structure, investigations had been made by the advisory council of the Harbor Commissioners that had led them to abandon this principle, and that consequently the reason for making these assessments having failed, the law requiring them should be repealed and the city relieved from this particular application of it.

No public hearing upon this subject was given by any committee of the city council, and no opportunity of explanation was afforded to this Board or the engineers whose supposed opinions seem to have been made the ground of action. The Board, however, is glad to believe that the legislature has only to intimate its desire that the law under which Atlantic Avenue was built should be complied with and the city authorities will cheerfully pay this assessment into the treasury of the State. For this reason no further steps have been taken for its collection.*

That there may be no question in the mind of any one what

* Mr. Quincy being an abutter and interested under the betterment laws, adversely to the assessment, has taken no part in the action of the Board on this subject.

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the judgment of the advisory council is upon this subject the Board have submitted to the council the following inquiry, and will at once transmit to the legislature their report in reply, as soon as it shall be received:—

"*Voted*, That the advisory council be requested to state to the Board their judgment as to the importance and expediency of applying the principle of compensation to the upper harbor of Boston, as prescribed in sect. 4 of chap. 149 of the Acts of the legislature of Massachusetts for 1866, and whether and to what extent any investigation made since the reports of the United States commissioners to the city of Boston, and particularly the investigations mentioned in the report of the advisory council to this Board appended to the report of this Board to the legislature of 1868, have modified the basis upon which the principle of compensation has been maintained."

South Bay.

The Roxbury Gas Light Company has made application to this Board for a revision of the harbor lines of South Bay in Boston. This is the only formal application upon this subject, but it has come to the knowledge of the Board that many owners of flats in this locality have desired such action and the revision will be made. Although the present lines were established no longer ago than the year 1864, still, within a few years the navigation on these waters has greatly increased, the lands bordering upon them have risen in value and been very rapidly occupied for business purposes dependent upon such navigation, and it is desirable that as much territory here should be surrendered for occupation as is consistent with the wants of navigation and the maintenance unimpaired of the physical function which South Bay performs in its relation to Fort Point Channel. Great changes also have, since 1864, been made in the bay by the location through it of the solid embankment of the Boston, Hartford and Erie Railroad. Were there no other reason for such revision, the serious errors in the text of the statute of 1864 would make a reënactment of the law necessary.

Wareham River.

During the past year the Board have had made a careful survey of Wareham River, with a view to the establishment of

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proper harbor lines and the determination of the causes that have led to the formation of shoals near the wharves. They also have it in mind to apply to Congress for the removal of the bar that has formed at the mouth of the river, should the results seem to justify such action. The great importance of this port and the extensive manufactures carried on there, call for a serious effort to improve the navigation of this river, upon which the prosperity of the place almost wholly depends.

Cape Cod Canal.

Although the Cape Cod Canal is the project of a private corporation, it is nevertheless a project for the construction of a great work of immense importance to the commerce of the country, and especially that of Massachusetts. It has long been a cherished scheme of the people of this Commonwealth. The company received its charter and franchises from the legislature with every evidence that the company had its earnest wishes for the success of the enterprise. On obtaining its charter, the company applied to Congress for aid in the construction of a breakwater in Barnstable Bay, to serve as a protection for the terminus of the canal and a means of obtaining safe temporary anchorage for vessels intending to pass through. The legislature gave its weighty sanction to this application. Regarding this work as peculiarly of that class for which the Board is authorized by the law establishing it, to apply to Congress for aid, it presented the memorial appended to this Report.

The action of the committees of both branches of Congress upon this application of the company was entirely satisfactory. The measure enlists there the hearty support of the senators and representatives from the Commonwealth, and no doubt is entertained of its final success. The company represent that as soon as the coöperation of the national government in the manner stated is secured, it is ready to proceed at once with the work.

Woods' Dam.

The Board on the 1st day of August last, upon the application of citizens of Medford and its selectmen, caused an information to be brought in the supreme judicial court against B. F. Woods of Arlington, to prevent him from re-constructing and

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maintaining a dam on the Mystic River in connection with his mill. For the last nineteen years there has been a standing controversy between the proprietor of this dam and the citizens of Medford, concerning the rightfulness of this structure. As often as it has been torn down by one party it has been replaced by the other, with such demonstrations of excitement and ill-will as continually to endanger the peace of the Commonwealth. In 1862 the City of Charlestown built in this locality, under authority of the legislature, and in connection with the establishment of its water works, tide-gates, which, by agreement with that city, Mr. Woods was permitted to use, in consideration of the removal of his dam. By the statute, the governor and council were authorized to remove these tide-gates whenever they saw fit, in case they were not removed by the city, and in 1867 the governor and council exercised this authority, and the gates were removed by the constable of the Commonwealth under executive order.

Thereupon Mr. Woods rebuilt his dam. In the season of boating on the river, citizens of Medford and the vicinity have from time to time, to a greater or less extent, removed the dam, and it has been rebuilt, and last summer, when the Board intervened, the dam had been torn down by a large concourse of citizens interested in maintaining the boating upon the river. The grounds upon which the legality of this dam is contested are :—

1. That it is an unauthorized structure in tide-waters flowing into Boston Harbor.
2. That it is an intrusion upon the bed of the stream, which is the property of the Commonwealth.
3. That it obstructs the public right of boating on this river.

A hearing has been had upon the facts, and the case is to be reported to the full bench. It is believed that a decision will be obtained before summer that will set at rest all questions of right now in dispute.

Reclamation of the Green Harbor River and North River Marshes.

The interest that has been taken by the inhabitants of Marshfield in the drainage of the marshes of Green Harbor River, and

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of the inhabitants of South Scituate in the drainage of North River, and the counsel sought by them in regard to these subjects, has, during the past year, opened to this Board a new field for service of the highest utility.

Last winter the county commissioners of the county of Plymouth obtained authority from the legislature to construct a bridge across Green Harbor River, which, under the laws of the Commonwealth, is to be exercised in a manner approved by this Board. It was the desire of many citizens of Marshfield that the new bridge should be so located, and that such a structure should be built as might serve at the same time the double purpose of a highway, and be used in the construction of a transverse sluice for draining the marshes of the river. Having received notice that when the question of the location of the highway arose, the claim would be asserted that this location should be fixed somewhat with reference to the drainage of these marshes, it became necessary for the Board to investigate the expediency and feasibility of the project.

It was an essential part of the plan for reclaiming the marshes on North River that a sluice dam should be constructed, which would keep out the waters of the ocean during flood tide, and during the ebb drain off the waters of the river. Such a structure would obstruct navigation, and require the sanction of the legislature, and to obtain this sanction the Board were desired to favor the undertaking. To do this, it became necessary in this case also, to investigate the expediency and feasibility of the project.

The marshes upon Green Harbor River comprise about fifteen hundred acres, and those of North River about three thousand more. They produce nothing but the least valuable of the grasses that grow on salt marshes. Reclaimed they would produce English hay or garden vegetables. These reclamations would benefit all the towns upon these rivers, and restore to some the prosperity which was theirs when they were centres of business that has since left them for the suburbs of great seaports. A generation or more ago, North River was devoted to ship-building. Some of the best ship-builders in the country obtained their early training in the yards on this stream. Not a vestige of them remains. The navigability of this river for the class of vessels that used to be built upon its banks was

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destroyed some years ago by inroads of the sea breaking through the natural shingle dike that separated its lower reach from the ocean and filling up the channel. An attempt afterwards to dig a new outlet through this dike failed utterly, and all hope of making this river again usefully navigable has long since been abandoned.

The magnitude of the interests involved in these projects was manifest. To obtain observations and calculations for the determination of the practicability of the drainage of these marshes by sluicing, the Board had recourse to Prof. Benj. Peirce, Superintendent of the U. S. Coast Survey, and obtained the heartiest coöperation in the proposed measures; inasmuch as all questions affecting the navigability of tide-waters are peculiarly within the province of his department.

Prof. Henry Mitchell, who is a member of the U. S. Advisory Council to this Board, was authorized to make the requisite observations and calculations for determining the practicability of the proposed projects.

Prof. Henry L. Whiting, who acts as engineer of this Board, was authorized to carry inland, as far as the marshes extended, the survey that had formerly been made of the coast at the outlet of North River, and make some additions to the existing coast survey maps of Green Harbor River.

These officers called for volunteers for this work, and they were promptly supplied by the Massachusetts Institute of Technology. The students gladly embraced the opportunity to take part in a work so practically useful, and to be so scientifically conducted. They brought to its aid the requisite acquirements and the true enthusiasm of engineers.

Green Harbor River.

Green Harbor River, regarded in its relations to the drainage of the marshes for agricultural purposes, by the employment of transverse dams and sluices is found to offer to the engineer no new problem, and the conditions to be fulfilled are so simple that complete success is sure to follow a faithful execution of works upon old and well-tried plans. In their relations to the harbor and its entrance, however, works of this character, it is believed, are not likely to remain neutral. Their effects must be considerable, because they will deprive the channel-way over the bar

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at the entrance of the harbor, of a scouring power which now serves to maintain there a depth of about two feet of water at low tide. Professor Mitchell shows that the ebb stream executes at the mouth of the harbor eight times as much scour as the flood, and that in this way the sands which would otherwise invade the basin are pushed back into the sea. He concludes, therefore, that in the course of time, after the construction of the sluice dam, the bar channel will fill up to the plane of low water so as to convert the basin into an exclusively tide harbor like those of Scusset and Sandwich.

In regard to the value of this harbor Professor Mitchell uses the following language:—

"The lower reach of the river is known as Green Harbor, whose length from Turkey Point to the bar is about seven-eighths of a mile, and whose maximum low-water width scarcely exceeds five hundred feet. A sand-bar obstructs the entrance, upon which there is from two to three feet of water at ordinary low tide. The average rise is nine feet, and vessels can take the ground within the harbor, at low tide, without injury. The shelter from winds and sea is good. As far as I could learn the trade of the place employs but one small vessel, but during the summer many small yachts for the accommodation of watering people make here a rendezvous. It is not entitled to the slightest consideration as a port of refuge, although vessels have been known to run into it under desperate circumstances."

Prof. Whiting reports upon this subject as follows:—

"As a small local harbor it also has some character. Once within the mouth of the river, a small vessel would find good anchorage, a sufficient depth of water and complete shelter. The entrance, however, is shoaler than the river within, and really cannot be called navigable at low water.

"Considered as a commercial port the whole available water is but of small extent.

"As a harbor of refuge, it will probably never be of use except by the local fishing boats and small pleasure yachts of the immediate neighborhood. For coasting vessels generally, or any craft seeking a harbor of refuge merely, the far more accessible and ample harbor inside the Gurnet, but a few miles southward, renders Green Harbor River of no value as a public refuge.

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"It is questionable whether the construction of a dike and gates, by shutting off the upper reaches of the marsh creeks as a reservoir, will materially affect the river below them, or injure the entrance to it.

"But even if this should be the case, at some remote day the reclaimed marshes will be of far greater value to the local community and to the town, county and State, as an agricultural district, than any use which can be made of the unimproved waters of the river."

It has, therefore, seemed to the Board that in comparison with the great benefits to the agricultural community that would result from the reclamation of the marshes, the probable effect upon the basin of this harbor was an inconsiderable matter, and that the public good in the premises plainly required that these benefits should be secured, although in the way that involves the least injury to this conflicting interest, slight as it may be.

Professor Peirce's very valuable "criterion for reclamation," finds its first publication in this Report, and is applied to the case of the Green Harbor River marshes. That the projected reclamation stands the test of this criterion is shown in the following extract from Professor Mitchell's Report:—

"The marshes are nearly at the level of high water in this portion of the basin, and supposing at the date of our observations, gates to have been closed upon the river at the time of low water, the accumulation behind them during the following six hours would have been according to Professor Peirce's criterion about three feet, so that the surface of the marsh would have been six feet above the water table at the time of high water in the Bay. This depth of three feet is largely in excess of the fresh-water supply, because many of the creeks do not fully discharge their tide-waters during the fall in the main river. Our hydrometer at low-water gave a density of 1.095; indicating that the outflow was then three-quarters sea-water. Indeed the current observations show that the fresh-water discharge was exceedingly small, and that gates of ordinary dimensions may be relied upon for draining this basin perfectly."

The question of the location of the bridge to be built across these waters has not been presented to the Board by the county

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commissioners. In view of the importance of this reclamation, and the great saving of expense that would be secured if the location and construction of this bridge could be determined with reference to this reclamation, the Board recommend the consideration of the expediency of such a modification of the Act of last winter, that the construction of this new highway may be made of service to this great agricultural improvement.

North River.

On the other hand, North River presents physical difficulties in the way of reclamation, which have been subjects of very careful inquiries in the peculiar field of investigations with which Professor Mitchell is charged in his department, and in which he has won such distinction as an engineer. He has spared no pains to determine the practicability of drainage, and at the same time has considered the physical phenomena presented by the river mouth and adjacent portions of the coast with which the problem of reclamation in this case is intimately concerned. He concludes that in spite of the large fresh-water supply afforded at certain seasons, the reclamation of these marshes can be effected by the construction of a single sluice dam. But to insure entire success, the beaches of shingle and sand that lie between the marshes and the ocean should be made secure against inroads of the sea by the construction of dikes at several weak places. The height to which these dikes should be carried he is able to compute from the study of shingle levees here and elsewhere. His comments upon shingle levees, which in our country appear only upon the New England coast, shows that these objects, so familiar to our eyes, play an important part in the economy of nature, and are worthy of the study not only of the curious inquirer, but of the practical engineer.

Another class of observations has led Professor Mitchell to fix definitely the minimum height for the sluice-dam to provide against overflow from the "general rise" during storms. He has taken for his standard the vertical elevation observed in Boston Harbor during the Minot's Light-house gale, and from that calculated the lesser elevation that must have occurred upon the open coast and at the mouths of little streams like Green and North Rivers.

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With regard to the rise of the water behind the proposed dam during the period that its gates must remain closed, a very close calculation is made, but the result is of course confined in its precise application to the period of his survey. He, however, indicates clearly the means that may be taken by a simple series of observations, for computing this element for other seasons, so as to ascertain exactly how much drainage must be provided for, in planning the sluice gates.

The section of Professor Mitchell's report which, incidentally, to this problem, discusses the origin of tide marshes is a part of his general study of the coast in which he gives the results of his own experience and that of other engineers in physical hydrography. All testimony is found to concur in attributing to the waves of the ocean the most active part in filling up the sheltered coves and harbors of the coast, and yet it seems to be equally true that great bays and gulfs are pushing their way into continents.

Upon the point whether after drainage these marshes will not sink, Professor Mitchell obtained satisfactory evidence from those who attempted to make the new channel through the dike as an outlet for the river. He says:—

"I glean one curious fact from those employed in opening this channel, viz.: the original bank of shingle was found to extend downwards only to the surface of the marsh, which was not sensibly depressed beneath its weight. I infer that as Fourth Cliff wears away the whole beach falls back and the present banks of sand and shingle are really superimposed upon ancient meadow lands or river channels. The marshes are not floating bogs like the *koogs* of Denmark or liable to slump down after enclosure, like the *polders* of Holland. The newly formed levee, across the mouth of the artificial outlet exerts a pressure of over 1,200 pounds to the square foot upon the marsh beneath its crest, and the weight of the original bank as far as I can judge, was over 1,700 pounds to the square foot under the crest. I have allowed in these estimates 25 per cent. for voids. Old rubble breakwaters, that have been shaken down by the waves to a state of repose, occupy still a space 25 to 30 per cent. greater than the rock *in situ*. Some shrinkage will no doubt take place after drainage is effected, but this will not, I think, exceed 10 to 12 per cent. If the *water table* is dropped four feet, I shall expect the marsh surface to sink about six inches."

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The following are the general conclusions of Prof. Mitchell's study of the two projects:—

1. The marshes of Green Harbor River may be drained by the construction of a sluice-dam at Turkey Point without unusual precautions or expense, but not without injury to the present facilities for navigation below said point.

2. The North River marshes can be drained by constructing a sluice-dam at White's Ferry, provided the present obstructions below are removed by dredging; and provided, also, that dikes are carried across the "slue-ways" of the beach to the height of thirteen feet above mean high water of the sea.

3. The dams to escape overflows from the "general rise" during storms, must be carried at least four and a half feet above mean high water of the sea.

4. The marshes after drainage will not sink or shrink more than twelve per cent. of their elevation above the "water table."

The results of Professor Whiting's survey of North River are represented on finely executed maps, which, with the enlarged coast survey maps of Green Harbor River, are given in one of the plans in the Appendix on a much reduced scale. The original map of North River has been drawn on a sufficiently large scale to be serviceable in carrying out the contemplated improvement. Professor Whiting's very interesting report in the Appendix gives the results of a careful discussion of these points:—

1. The value of the inlet at North River as a harbor, of the river for commerce and navigation, and of the marshes for agriculture in their present condition.

2. The probability of the river ever becoming by natural causes navigable, or of any substantial change occurring in the character of the marshes.

3. The probability that this river or the inlet will ever be improved so as to be made of value again for ship-building or navigation.

4. The practicability and profit for agriculture of converting these salt marshes into fresh, drained meadows.

His conclusions on all these points are favorable to the proposed reclamation.

In view of these results the Board do not hesitate to recommend the passage of a law authorizing the construction of the sluice-dam on North River, requisite for the reclamation of its

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marshes. When this has been built there should be some penal legislation to protect the shingle dike between Third Cliff and the mouth of the river from the practice that has heretofore prevailed of removing material from it to be used for ballast and paving stones. This dike will form the sole barrier of these marshes against the sea in storms, and will be necessary for the security of the improvement when once made. It becomes the muniment of a most valuable property and should have thrown around it all the safeguards of the law.

Authority also should be given for the occupation, subject to the approval of this Board, of so much of the beds of Green and North Rivers as may not be needed for drainage.

The Board is not aware that any reclamations of salt marshes have been made in this Commonwealth upon the large scale proposed in these plans for Green Harbor and North Rivers.

In Europe such reclamations are common. In Nova Scotia they have been undertaken with complete success. Very recently in New Jersey the drainage of the Newark meadows has been attempted, and the results thus far are full of promise and encouragement. There must be many thousands of acres of salt marshes in this Commonwealth that could be made to yield the most abundant and profitable harvests. These soils are of the richest character and worked with the greatest ease. They only need drainage and protection from inundation from the sea. In many cases these can be secured without too large an outlay for a handsome profit. Such reclamations are positive additions to the wealth of the State, and the Board is glad to be able to promote them.

Government Work in Boston Harbor.

The work in Boston Harbor under General J. G. Foster of the United States Engineers, has made during the past year most satisfactory progress. Congress made an appropriation of $100,000, which with the unexpended balances of prior appropriations has been used for the reduction of Kelly's Rock, the dredging away of the upper middle bar, the completion of a sea-wall around Gallop's Island, and the commencement of the sea-walls around Long Island and Point Allerton. These works in progress, together with others in Boston Harbor which have been completed during the last three years, comprise nearly all

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that were selected by the United States Engineer Department as of pressing and absolute importance from the scheme of improvement presented and urged upon Congress by this Board in the first year of its organization. The appropriations thus far on this basis have amounted to $516,000, and under the wise and efficient administration of the engineer department and of General Foster in charge of the work, they have been expended to the best advantage. The report of General Foster, with the map illustrating it in the Appendix, shows in detail what has been accomplished and what remains to be done. It is a document of great interest and value. It embraces in its scope an admirable statement of the beautiful adjustment of things through which Boston Harbor was made by nature one of the finest in the world, describes the rapid deterioration it underwent in consequence of the improvident sacrifice of great natural advantages for the sake of trivial gains, and by reason of the neglect of proper remedies, and demonstrates the necessity of all the measures that have been taken to arrest further decline. It conveys an impressive admonition not to imperil for the sake of immediate but not indispensable benefits the indispensable conditions upon which the maintenance of Boston Harbor and the vast interests connected with it depend, and inculcates the duty of transmitting to future generations, of larger expansion even than our own, this noble organ of commerce with the world.

Government Work Elsewhere.

Other government works for the improvement of the harbors and navigable waters of the Commonwealth have been successfully prosecuted during the past season, under General Foster's charge.

In Newburyport Harbor the wreck of a coal schooner lying in the channel just inside the entrance, has been broken up by blasting and the fragments removed by divers.

At the "Lower Falls" in the Merrimack River a channel for canal-boat navigation has been excavated nearly through the rapids. The completion of this cut, and also a similar one through the "Upper Falls," will secure for the cities of Lawrence, Lowell and others on the river, the benefits of cheap water transportation in barges from Newburyport.

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At Gloucester a survey of "Dog Bar," at the entrance of the harbor, and also of the rocks in the inner harbor has been made. In the former survey the Board has coöperated with a view, should the results justify such a course, of petitioning Congress for an appropriation for the improvement of this harbor, and the construction of a harbor of refuge at its entrance. An enlargement of the safe anchorage ground of this most important and enterprising port is greatly needed.

At Plymouth Harbor works have been constructed for the preservation of Long Beach similar to those recently applied with success for the preservation of Beach Point in Provincetown Harbor.

In Provincetown Harbor the construction of brush and stone protections for the exposed beaches, and dikes to check the rush of the tides through open reaches, has been extended so as to allay all apprehensions of further injuries at present.

At Hyannis the completion of the breakwater, by building up the upper courses, has been carried forward during the past, and is to be continued during the next season.

In the Taunton River operations were commenced for the removal of the shoals, which are met, at intervals, for a distance of three and a half miles below the city of Taunton. The machinery employed proving inadequate active operations were postponed until next season, when good progress is anticipated. This improvement is of material interest to the commerce of the city of Taunton, which will be much benefited thereby.

Duplication of the United States Coast Survey Maps for Massachusetts.

The Board respectfully urges upon the attention of the legislature the considerations presented in the last report in favor of the duplication of the maps of the United States survey of the coast of this State.

The increasing demand for a better knowledge of the harbors and shores of the Commonwealth, such as accurate surveys alone can give, has made the want of such surveys outside of Boston Harbor, a serious embarrassment to the Board in their investigation of the subjects referred to them. The possession of the results of the Coast Survey would supply the needed data. Arrangements can be made with the superin-

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tendent of the Coast Survey, and with his office, by which copies of the original maps can be obtained. This will give to the State, for the mere expense of copying, surveys that have cost the general government several hundred thousand dollars. Prof. Peirce, the superintendent of the United States Coast Survey, is willing not only to coöperate with the Commission in this undertaking, but urges its accomplishment as a measure of advantage and value to the government and to the State by providing *duplicates* of the original maps. The only record of these expensive and elaborate surveys is contained in the original maps, which are on a larger scale than any of those engraved and published.

The Coast Survey Department would favor any arrangement which would secure a duplication of these maps and their safe deposit in the archives of the various States; in fact, the practical execution of some plan effecting this general result has been for some time a matter of consideration by this department. Hardly any State bordering on the Atlantic has a greater extent of coast or more important harbors, in proportion to its territory, than Massachusetts, and, therefore, none is more interested in securing accurate knowledge in regard to them.

The number of the original topographical maps of the Coast Survey covering our State territory is between fifty and sixty. These are on the large scale of $\frac{1}{10000}$, or about six inches to the mile, and generally extend back from the coast line to the first shore road giving land communication from port to port. Added to these would be the in-shore hydrographical maps, which are fewer in number.

The copying of these maps will be a work of probably some two or three years, as it would not be desirable to organize a large office force to accomplish it in a more rapid manner, and all the maps could not be spared from the office of the Coast Survey, for this service, at one time.

The Board would be particularly favored in this work by the service of their engineer, Prof. H. L. Whiting, who is one of the senior officers of the Coast Survey and chief of its department of field topography.

We are unable at this time to give a detailed estimate of the cost of the entire work proposed, but will submit one should it

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be required. In general terms, the following estimate is submitted:—

60 topographical maps, at $200 each, . . .	$12,000 00
40 hydrographical maps at $150 " . . .	6,000 00
Office and other incidental expenses, $1,000 a year for three years, ...	3,000 00
	$21,000 00

One-third of this amount would be sufficient as a first appropriation, ... $7,000 00

It is safe to state that the general government has expended, in its survey of the coast of Massachusetts, not less than $500,000, the practical benefit and value of which can be possessed by the State government at a cost of but about $20,000.

Protection of the Harbors of the Commonwealth.

The Board also request some legislation, that shall enable it to protect more effectually, the channels and anchorage grounds of the harbors of the Commonwealth, from the practice of throwing ballast and other materials into them, which are of injurious tendency. Applications have been made to the Board to prevent such practices, and the Board is charged by law with the duty of preventing them. But more legislation is needed to make such practices clearly recognized and penal offences. Some such protection as the law gives Boston Harbor, should be given to all the harbors of the State, or the essential parts of them.

Plans Approved.

The Board has approved plans, during the past year, for the erection of structures in or over tide-waters as follows:—

For the extension of the south pier of Lewis Wharf in Boston.—*Approved March* 23, 1870.

For the construction of a bridge over Mitchell's River at Chatham, by the County Commissioners of Barnstable County. —*Approved April* 8, 1870.

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For widening and extending certain wharves in Gloucester Harbor, by David Low & Co.—*Approved April* 8, 1870.

For widening a wharf in Gloucester Harbor, by Dennis & Ayer.—*Approved April* 8, 1870.

For building a wharf on the south-easterly side of Albany Street, in Boston, by Joseph F. Paul.—*Approved April* 15.

For construction of pile wharves to the Commissioners' line in Boston Harbor, by the Boston Gas Light Company.—*Approved April* 27.

For driving piles in Fort Point Channel in Boston Harbor, in the reconstruction of Mt. Washington Avenue Bridge, by the City of Boston.—*Approved May* 4.

For the construction of a wharf in South Bay, Boston Harbor, to the Commissioners' line, by John W. Leatherbee.—*Approved May* 4.

For the construction of a wharf in South Bay, Boston Harbor, by A. R. Whittier.—*Approved July* 6.

For the extension of a wharf in South Bay, Boston Harbor, by Nathaniel Winsor.—*Approved July* 6.

For the construction of a bridge across the channel-way, connecting Lagoon Pond with the waters of Holmes' Hole Harbor, by the County Commissioners of Dukes County.—*Approved July* 27.

For the construction of a wharf in South Bay, Boston Harbor, by Seth Whittier and A. R. Whittier.—*Approved August* 3.

For filling solid Hosley and Russell's Wharf in Fort Point Channel, Boston Harbor.—*Approved August* 24.

For the construction of a bridge across Duck Creek in Wellfleet, by the Cape Cod Railroad Company.—*Approved Aug.* 24.

For the location and construction of a new bridge across Merrimack River, between Grovehead and Haverhill, by the County Commissioners of Essex County.—*Approved Sept.* 1.

For the location and construction of a new draw in the Boston and Maine Railroad bridge over Charles River.—*Approved Oct.* 27.

For the construction of a wharf in Weymouth Fore River, by Thomas J. Dunbar.—*Approved Dec.* 14.

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STATEMENT OF ENGINEER AND OFFICE WORK.

The special surveys and other field work executed by the engineer, by order of the Board are as follows:—

In Hingham Harbor a survey has been made of a portion of the main channel with its surroundings, together with the examination of a rock in this channel, below the steamboat wharves. A copy of this survey with a statement of the condition of the river and the character of the obstruction caused by the rock above mentioned, was transmitted by the Board to the Chief Engineer of the Army, Gen. A. A. Humphreys, as the basis of an appeal to the general government to improve the navigation of the harbor by the removal of the rock.

In Charles River, or Cambridge Basin, so called, a detailed survey has been made of the shoal above or south of West Boston Bridge, near the location of the present draw.

A survey has been made determining the amount of solid filling over the original ground of the South Boston flats.

A survey has also been made of the South Boston flats proper, determining the changes and injuries which have occurred since the suspension of the work of building sea-walls and depositing material within the territory of the Boston, Hartford and Erie Railroad.

Field determinations have been made establishing the Commissioners' line in South Bay, along the front of the Boston Gas Works in Charles River, and for the extension of Lewis Wharf. The line of the draw-way openings through the railroad bridges over Charles River, has also been established.

An extensive and elaborate survey has been made of Wareham River from above the town and railroad bridges to the chops of the river at the head of Buzzard's Bay. The topography, hydrography and tidal observations embraced in this survey required a month of working time for a large field party. The purposes of this survey as the bases for a scheme of river improvement, have been already stated. The result, in the form of an elaborate map, with plans for harbor lines, will be made the subject of a special future report.

Field reconnaissance, examination and sketches have been made in Gloucester Harbor, in Weymouth Fore River, in Wellfleet Harbor and in South Bay in Boston Harbor and also of

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the shingle dike in Scituate, and of North River, South River, and Green River.

In addition to the surveys made by direct order of the Board, they have coöperated in the surveys of the North River and Green River, made under the direction of Prof. Peirce, Superintendent of the United States survey by his assistants, Profs. Whiting and Mitchell, reports concerning which are appended to this Report.

In connection with these operations the Board visited the ground of the contemplated reclamation of the marshes of the North River, and met at North Marshfield several of the parties interested in this important improvement.

The Board have also visited the ground of the proposed Cape Cod Canal.

The office work executed during the year has been varied and continuous. The inquiry for data, and the information furnished to parties, public and private, who have interest in navigable tide-waters and harbor, river and coast improvements, show an increasing demand for the service and supervision of the Board, and the value of its archives.

At the solicitation of the Board, the data were furnished from the United States Coast Survey office at Washington, for an accurate duplicate of the large and valuable chart of Boston Harbor, made for the United States Commissioners by Mr. A. Boschke in 1861–2. Office work has been continued in the details of this chart and is still in progress.

The drawings, plottings and copy of the map of Wareham River, on a large scale, are also in process of completion.

Of miscellaneous office work the following plans and sketches have been made :—

Showing the location of new draws in Cragie and Prison Point Bridges, ...	6 plans.
Location of draw in West Boston Bridge, .	1 plan,
Location of draw in upper Lowell Bridge, .	1 "
Location of draw in Boston and Maine and Eastern Railroad bridges, ...	1 "
For Railroad and Harbor Commissioners, showing bridges in Charles and Miller's Rivers, .	1 large map.

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Showing railroad terminal ground in Boston, Charlestown and Cambridge, ...	2 large maps.
Showing comparison of soundings between surveys by Messrs. Wadsworth and Boschke, .	1 map.
Part of Hingham Harbor, ...	1 "
Copy from Registry of Deeds in Dedham, .	1 "
Thompson's Island, showing limits of ground for the removal of gravel, ...	1 plan.
Spectacle Island, for deepening the approaches to Ward's Wharf, ...	1 "
For Roxbury Gas Light Company, showing Commissioners' lines in South Bay, . .	1 "
Fender guard for fender pier of Broadway Bridge, over Fort Point Channel, . . .	1 "
Atlantic Avenue Sea-wall, ...	1 "
Roxbury Canal, South Bay, ...	1 "
Part of South Bay, for Legislative Committee,	1 "
For Railroad and Harbor Commissioners, showing boundaries of real estate in Cambridge, .	1 "
Showing estates between Lowell and Leverett Streets, ...	1 "
Showing estates between Causeway Street and Haymarket Square, ...	1 "
Showing filling on South Boston flats, . .	1 sketch.
Showing trenches and sea-wall, South Boston flats, ...	1 "
Shoal above West Boston Bridge, . . .	4 sketches.
Location of Rock in Hingham Harbor, . .	1 sketch.

Numerous minor sketches and extracts from plans and charts furnished to various parties, have not been made matter of record.

Organization.

The Board still avails itself of the counsel of General J. G. Foster, of the United States Engineers, in all matters of constructive engineering that come within the jurisdiction of the Board. Prof. Henry L. Whiting of the United States Coast Survey, with the consent of the Superintendent, acts as engineer of the Board, and has Mr. D. Koppmann as his assistant

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in field and office work. Rear Admiral C. H. Davis, Gen. A. A. Humphreys, Chief of the United States Engineers, Prof. Benj. Peirce, Superintendent of the United States Coast Survey, and Prof. Henry Mitchell, chief of physical hydrography in the U. S. Coast Survey, aid the Board as an Advisory Council, especially in difficult questions requiring scientific investigation. By this organization the Board maintains intimate relations with the authorities of the United States, who have an official interest in the navigable waters of Massachusetts. The general government is thus enabled readily to appreciate the needs of the State, and the State to understand the wishes of the general government, and both to act in harmony for the public good.

JOSIAH QUINCY.
DARWIN E. WARE.
F. W. LINCOLN, Jr.
J. N. MARSHALL.

January 10th, 1871.

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APPENDIX.

MEMORIAL IN BEHALF OF THE CAPE COD CANAL.

[TRANSMITTED TO HON. JAMES BUFFINTON, MAY 19, 1870.]

To the Senate and House of Representatives of the United States in Congress assembled.

The undersigned, constituting the Board of Harbor Commissioners of the Commonwealth of Massachusetts, and charged with authority, among other things, to apply to Congress and in proper cases for the protection and improvement of the harbor facilities of the State; in pursuance of such authority in discharge of their duty, respectfully present the following memorial:—

From an early period after the settlement of the Plymouth Colony to the present time, the project of connecting the waters of Barnstable and Buzzard's Bay, by an artificial navigable channel, to avoid the necessity of making the long and dangerous passage around Cape Cod, has been much discussed and earnestly advocated.

In the investigation of this subject several elaborate surveys of a route have been made by private enterprise, and by the direction of the State and the nation. Every such investigation has resulted in a new demonstration, not only of the practicability, but the easy practicability of the project, especially when judged by the difficulties that have often been surmounted by individuals and governments to secure inferior advantages

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of the same kind. Natural depressions formed by the valleys of the Scusset and Monument rivers, and extending across the isthmus, separating the two bays by a space about seven miles wide, together with a soil that shows an entire absence of ledges, and is not hard to excavate, furnish the most favorable conditions for the construction of the work.

The temperature of the waters of Barnstable Bay in winter is such as to make it reasonably certain that the navigation of the canal will not be stopped by ice in the coldest weather.

The saving in distance that can in this way be effected for vessels going by Long Island Sound to or from any port in Massachusetts Bay is about one hundred and forty miles, and two hundred miles for vessels going by the ocean route below the Sound. This saving in distance represents an annual saving of over six hundred thousand dollars in the cost of transportation.

Moreover, the passage around Cape Cod is an exceedingly perilous one. The wrecks of over a thousand vessels, and the loss of many hundred lives, bear witness to the dangerous character of this coast, and the ruin it has caused in only a single generation. This mere element of danger to navigation, by increasing the rates of insurance for voyages around Cape Cod, occasions a pecuniary loss to the commerce of the country in addition to that which results from the actual destruction of property. It would require to capitalize this annual loss in the form of a principal fund bearing an annual interest of six per centum, sufficient to compensate the loss, over three millions of dollars, a sum which would go far towards paying the cost of the canal.

In view of these facts, it is surprising that this work was not long ago undertaken and completed by the United States or by private parties. It is, however, easy to understand that the government might not be disposed to embark in the undertaking except upon a basis that would insure an income sufficient to reimburse to it the interest on its expenditures, and that it would be inclined to believe that upon such a basis it was a more suitable undertaking for private than for public enterprise.

On the other hand, the construction of the canal on the route that has found most favor involves a large expenditure for a

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breakwater at the terminus on Barnstable Bay, which, though indispensable, requires for its construction the sinking of so much capital that does not contribute to the main work of the canal proper, that capitalists have naturally been reluctant to undertake to carry through a project encumbered by so heavy a burden. The appropriate solution of all difficulties in regard to the terms upon which this great work may best be undertaken, would seem to be found in a plan which should assign to private capital the part of building and working the canal, and to the national government the construction of the necessary breakwater in Barnstable Bay.

The Commonwealth has already given a charter to several responsible gentlemen, who command the confidence of the people of Massachusetts, to construct this canal, and the Cape Cod Canal Company established under this charter is ready, in the belief of the undersigned, to enter upon and vigorously prosecute to completion the proposed work, as soon as they are authorized to rely upon the national government for the coöperation that has been suggested.

The undersigned earnestly hope that this coöperation may be given.

They would respectfully represent that an important purpose for which the breakwater in Barnstable Bay is required is to furnish a sheltered roadstead for vessels entering and leaving the canal, and that this roadstead ought to be available as a harbor of refuge. There is need of such a harbor upon that part of the coast. With it vessels would not run the risks they now do in stormy weather to make Boston Harbor, and to avoid the fatal bight of Barnstable Bay. But a harbor of refuge to vessels in distress ought not to be the private property of a private corporation. It should belong to the nation, and only the common country should control and administer its beneficent advantages. That it may belong to the nation, the national government should build it.

It is further respectfully suggested that the great benefits it is shown will accrue to the commerce of the country from the construction of this new route of navigation, are of the same class as those to secure which appropriations are annually made by Congress for the improvement of the rivers and harbors of the country, and aid is furnished to railroads. This canal

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would also be a step towards the entire canalization of the Atlantic coast, a measure that would conduce so much to economy in transportation, and to the safe prosecution of the coasting trade, both in time of peace and of war, that the promotion of such a measure might well be adopted as the settled policy of the United States.

More than all, the coöperation of the national government may be claimed on grounds of humanity.

Had the disasters that have attended the voyages around Cape Cod in the last thirty years been concentrated upon a single shoal or ledge of rocks, the appeal that would have gone up to a humane government from a thousand wrecks and hundreds of ocean graves, for buoys and light-houses and all the means of safer navigation would have been irresistible, and appropriations would have been made without stint. Yet, just the same validity and force, the undersigned do not hesitate to say, has the claim of the project of connecting Buzzard's and Barnstable bays by a navigable canal, upon the humanity of the national government.

For these reasons the undersigned respectfully commend the application of the Cape Cod Canal Company for an appropriation for a breakwater in Barnstable Bay, in connection with their works, to the favorable consideration of Congress.

JOSIAH QUINCY.
S. E. SEWALL.
D. E. WARE.
F. W. LINCOLN, Jr.
J. N. MARSHALL.

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REPORT OF PROFESSOR MITCHELL.

To the Board of Harbor Commissioners of Massachusetts.

GENTLEMEN,—In response to your letter to Professor Peirce, Superintendent United States Coast Survey, asking for a copy of that portion of my report which relates to physical surveys upon the Coast of Massachusetts, I send the following extracts which cover the portion of my work which was included in the project of the past season by request of your Board.

HENRY MITCHELL.

GREEN HARBOR RIVER.

This *river*, so called, is the drain of about fifteen hundred acres of marshes situated mostly in the township of Marshfield. It receives two considerable tributaries, and innumerable brooks and creeks in its meandering course. The lower reach of the river is known as Green Harbor, whose length from Turkey Point to the bar is about seven-eighths of a mile, and whose maximum low water width scarcely exceeds five hundred feet. A sand-bar obstructs the entrance, upon which there is from two to three feet of water at ordinary low tide. The average rise is nine feet, and vessels can take the ground within the harbor at low tide without injury. The shelter from winds and sea is good. As far as I could learn the trade of the place employs but one small vessel; but during the summer, many small yachts, for the accommodation of watering people, make here a rendezvous. It is not entitled to the slightest consideration as a port of refuge, although vessels have been known to run into it under desperate circumstances.

It has been proposed to reclaim the marshes by constructing a sluice-dam at the head of the harbor, and I visited the scene during

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the month of June with the twofold object of determining the practicability of this reclamation, and the likelihood of resulting injury to the entrance. The problem of reclamation presented is one of the simplest kind, and I was enabled to reach a positive result from a few experiments and a very limited survey; but the question of injury to the entrance has perplexed me very much. I shall offer, however, an argument upon this point.

The place chosen for gauging the river was near Turkey Point, where the uplands approach the stream on either hand, and where a dam could be most economically and effectively constructed. The table which follows furnishes the elements for a profile of the section from upland to upland crossing the river at the place of gauging. (See Fig 4.)

The tide was observed for thirteen hours upon the 30th of June. The range was 8.90 feet, which is about what I should compute for Cape Cod Bay at the same age of the moon, and no unusual distortion of the profile could be detected. The marshes are nearly at the level of high water in this portion of the basin, and supposing, at the date of our observations, gates to have been closed upon the river at the time of low water, the accumulation behind them during the following six hours would have been, according to Professor Peirce's criterion, about three feet, so that the surface of the marsh would have been six feet above the water table at time of high water in the bay. This depth of three feet is largely in excess of the fresh-water supply, because many of the creeks do not fully discharge their tide waters during the fall in the main river. Our hydrometer at low water gave a density of 1.0195, indicating that the outflow was then three-quarters sea-water. Indeed the current observations show that the fresh-water discharge was exceedingly small, and that gates of ordinary dimensions may be relied upon for draining this basin perfectly.

The river at its embouchure flows into the sea in a course but little to the eastward of south, with rocks upon its left and sands upon its right bank. These sands driven by the waves, and the flood current, are constantly invading the river's mouth, but are driven back by the outflow, and the bar is for the most part formed of material from outside, which is left in the debatable district between the opposing forces. I think that it is only during heavy weather that the flood current, aided by the waves, can overbalance the scour of the ebb, even during dry seasons when the fresh-water outflow is itself too small to be considered, and I base my opinion upon the following considerations:—The shifting material is sand, and this is not suspended, but rolled or driven along upon the bottom at a rate

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far less than that of the water itself, so that the progress that it ultimately makes, and the direction it takes, must be determined by the power and direction of the resultant of the forces, precisely as if these forces acted simultaneously. Now although the flood and ebb, at low river seasons are essentially the same as regards volume, they are quite unlike as regards velocity, *i.e.*, working power. The veins and arteries of the marshes are filled late and drained late as regards the tidal time at the mouth of the river, so that the greatest inflow is called for when the water is high upon the bar, while the greatest outflow is so much behindhand as to reach the bar when the latter has but a small section; the former therefore creates but little horizontal motion, while the latter creates a rapid current. When we consider that the work of a stream increases with the square of its velocity, we should not be surprised to find the ebb at the mouth of a river playing the dominant part in the excavation of channels. For instance, when the tide at our station had risen two feet or less than one-fifth of its range, the velocity of inflow was 0.50 feet per second, but when it had fallen to the same stage the outflow was 1.40 feet,—in other words the working power in the same section was *eight times as great upon the ebb as it was upon the flood.* If a sluice-dam were to be constructed, shutting out the tides from the marshes, the fresh-water outflow only would be left to resist the action of the waves, and as far as I can judge, the summer discharge would be impotent. In the introduction to this Report I have pointed out instances of little harbors that have been injured by weirs and dams, like that proposed for Green Harbor River, and I have little doubt that a decline in the depth on the bar will follow the reclamation of the marshes. It is true that the direction of the embouchure is favorable as regards shelter from the sea, and that the supply of material is not so great as at many points along shore, but I have about made up my mind that in course of time, after the dam is constrncted, the inlet will become a "tide harbor," like Scusset and Sandwich, *i.e.*, dry at low tide, at least upon its bar.

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Section of River at Turkey Point, (Fig. 4.)

Distance in feet.	Height above Low Water of June 30, in feet.	Remarks.	Distance in feet.	Height above Low Water of June 30, in feet.	Remarks.
0	13.46	Upland, left bank.	838.	9.17	On left bank of main stream.
36	12 29				
59	10.00	Edge of upland.	856.	1.60	River bed.
131	9.61	Marsh, salt grass.	858.	0.20	" "
196.8	9 33		868.	—4.2	" "
262.4	9.01	(Plane of high water=8.90.)	878.	—5.8	" "
318	8.63		888.	—4.9	" "
393.6	8.74		898.	—6 0	" "
459.2	8.99		908.	—6.2	" "
524.8	8.62		918.	—6.3	" "
557.6	8.99		928.	—6.9	" "
590.4	8.47	Left bank of stream.	938	—6 2	" "
600	2.4	River bed.	948.	—6 1	" "
610	1.4	" "	958.	—5 4	" "
620	0.6	(Plane of low water=0 00.)	968.	—5.0	" "
630	—0.3	" " "	978.	—2.1	" "
640	—0.3	" " "	988.	—2.2	" "
650	—1.0	" " "	998.	—2 2	" "
660	—1.1	" " "	1,008.	—1.2	" "
670	—1.1	" " "	1,018.	—0 4	" "
680	—1.1	" " "	1,028.	0.2	" "
690	—1.1	" " "	1,038.	0.8	" "
700	—1.2	" " "	1,045.	1.6	" "
710	—1.2	" " "	1,088.	4.05	Right bank of main stream.
720	+0 7	" " "			
730	8.59	Right bank of stream.	1,137.4	8.61	Marsh.
772.6	8.88	On island.	1,186 6	9 45	
798.6	8.65	" "	1,207.2	10.40	
835.	9.34	" "	1,269.	11.11	Turkey Point, bushes.

Professor Peirce's criterion, to which I have referred upon a preceding page, is a useful generalization, and the first in this particular branch of engineering that has come to my knowledge. It is a rule for deciding upon the propriety of attempting to reclaim the marshes of a tidal river by the construction of a transverse sluice-dam. It was offered expressly for a guide in the cases before the Massachusetts Board of Harbor Commissioners, and finds its place properly in this Report, although somewhat technical.

Professor Peirce's Criterion.

"Draw a tangent to the tidal curve at the point where the tidal current changes from ebb to flood; if this tangent intersects the descending branch, the reclamation will preserve from overflow all the land which is higher than the point of intersection."

In explanation of the above, it is simply necessary to state that the river supply is regarded as uniform, and therefore to be represented upon the diagram as a straight line, which will, of course, be

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the prolongation of that which represents the rise at the moment of *slack-water*, when the outflow and inflow are in equilibrio. If, as is usually the case at the mouth of a river, the observed curve is nearly that of the sines for a circle whose radius is half the range of the tide, reclamation is possible if the flood current begins to run up *within* 1 hour 43 minutes after the time of low water. If slack-water occurs at the instant of low-water stand, drainage of the marsh to a depth equal to the range of the tide is practicable; but if the flood current does not commence to run up until 1 hour 43 minutes after low water, the fresh-water accumulation, while the sluice-gates are closed, will equal the range of the tide. Fig. 2d of our plate illustrates these two cases.

This general rule is not applicable to the case where a bar, transverse to the river channel, below the observer, obstructs the propagation of the complete tide wave. In the case where a "submersible" dam exists, the rising curve within the obstruction resembles that observed outside, except that the lower portion, to the height of the dam, is cut off. If, for instance, the dam is elevated to the height of half tide, no tangent to the tidal curve within, will intersect the descending branch, and yet the case may be one of possible drainage to an adequate depth. In Fig. 3 I offer curves plotted from simultaneous observations near Hyannis, Massachusetts, in which the larger tide is that of the harbor, and the smaller that of Dunbar's Salt Pond, which is separated from the harbor by a natural bar, considerably elevated above the plane of low water outside, although never dry. No fresh-water feeders exist, and drainage to the level of the bar is of course possible, although the criterion (misapplied to the case) would say not.

North River.

Dean's History of Scituate published in 1831, furnishes a brief description of the North River which I shall quote, not only because as a general sketch it is still sufficient, but also because it comments upon the facilities for ship building and navigation which the river afforded before the recent disastrous inroads of the sea.

"This stream received its name before 1633, and probably from the circumstance that its general course is from south to north, or that it was farther north from Plymouth than South River in Marshfield, which meets the North River at its mouth. The North River is a very winding stream, flowing through extensive marshes, sometimes as it were, sporting in the broad meadows in the most fanciful meanders, and sometimes shooting away to the highlands which border the meadows. There is one reach which has long been called the 'No Gains' from the circumstance that, after flowing from

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side to side, and almost turning backwards for several times, it has in fact flowed several miles, and gained but a few rods in its direct progress to the sea. From the sea to the North River bridge on the Plymouth road, an air-line would not exceed seven miles; while the line of the river amounts to eighteen miles. The tide rises at the North River Bridge from three to five feet, and there is a perceptible tide two miles higher up. It has three chief sources, the Namatakeese and Indian Head, which flows from the Matakeeset Ponds in Pembroke, and the Drinkwater, which has its sources chiefly in Abington. The tributaries are the three Herring brooks on the Scituate side, and the Two Mile brook and the Rogers' brook on the Marshfield side." * * * "Just below and at an air-line distance of a little more than three miles from North River Bridge, is Union Bridge. A half mile lower on the Scituate side is King's landing. And about half a mile on the same side, is Hobart's landing. Here we believe the first vessels were built, by Samuel House, as early as 1650." * * * "Here the ship Columbia (Capt. Kendrick) was built by James Briggs, A. D. 1773. It was the first ship that visited the northwest coast from this country. Capt Kendrick explored the river Oregon, and named it from the name of his ship, which name will probably prevail henceforth. At the distance of another half mile below, is Little's Bridge, at which point we believe vessels have been built on the Marshfield side. The meadows above this station are of very various width, in few places exceeding a mile; but below there is a wide expanse of marsh, anciently called the 'New Harbor marshes.' The scenery here is on a sublime scale when viewed from Coleman's hills, or from the Fourth Cliff. The broad marshes are surrounded by a distant theatre of hills, and the river expands and embraces many islands in its bosom. Here it approaches the sea, as if to burst through the beach, but turns almost at right angles to the east, and runs parallel with the seashore for nearly three miles before it finds its outlet, leaving a beach next the sea for nearly twenty rods in width, composed principally of round and polished pebbles, excepting only the Fourth Cliff, a half mile in length, which comprises many acres of excellent arable land. Nearly a mile above the river's mouth is White's Ferry, where is a wharf and a small village on the Marshfield side. Here vessels have been built, and many that have been built above here receive their rigging. The river's width may be estimated as follows: In ordinary tides, at Union Bridge, seven rods; at Little's Bridge, nine rods; it expands below to a half a mile in width, where it is now called Fourth Cliff Bay and formerly New Harbor; here the channel divides, and unites again a mile below; a half a mile above its mouth it is fourteen rods in width. The channel at its mouth often shifts its place owing to the nature of the sandy bottom, and to the violence of the stream and the tides It seldom affords more than nine feet of water, even when there is but one channel; but it often happens that there are two channels, when the water is something less. This fact accounts for the difficulty and expense of carrying out the vessels built upon this river; and yet only in part, for there are shoals above, over which vessels of 200 tons and upwards must be lifted with gondolas or heaved with kedges. The principal are Wills' Shoal at the upper part of the New Harbor Marshes, and the Horseshoe Shoal."

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Since the above statement was written, 40 years have elapsed, during which, important physical changes have occurred, which, in connection with other circumstances, have led to the total abandonment of all commercial enterprises upon the North River; and the project now entertained for reclaiming the marshes by sluicing out the tide, involves the sacrifice of no interests of navigation.

The injuries which the channel-way has suffered have been principally due to the waves, which, during violent storms, have burst through the narrow strip of beach that separates the lower reach of the river from the ocean. Appreciating the importance of this natural dike in connection with the projected reclamation, I devoted some time to its inspection with a view to pointing out its weak places. With the exception of Fourth Cliff, which appears to be the smaller portion of a high hill, once extending into the sea, the entire beach is but a windrow of sand and stones cast up by the waves and subsequently modified in part by the winds, differing only in matters of detail from the *littoral cordon* of our Southern States.*

Shingle Levees.—A portion of this beach is permanent, the forces which created it, having, as it would seem, ultimated their effects. I refer here to the shingle levee, which from the point where the stream "*approaches the sea as if to break through,*" extends like a strong bulwark half way to the river's mouth, interrupted only by Fourth Cliff from whose waste a portion of the material of the levee seems to have been selected.

It is not impossible that the river once found its outlet between the Third and Fourth Cliffs, as most of the people living in the neighborhood conceive. Instances are numerous where streams have been turned aside, and sometimes cut off from the sea, by the advance of shingle. Indeed the whole phenomenon may be said to belong especially to the present time, geologically speaking, and many of the most striking exhibitions of it fall within the historic period. For instance, the Romans found at Dover, an estuary without any obstruction from shingle; many years after, however, there advanced along the coast a ridge of this material, and eventually the old port was ruined, the efforts to save it having been commenced too late. Nearer home than this we are witness in our own times of the steady advance of a shingle levee (Brewster Bar)

* Of our Atlantic sea board from Quoddy Roads to Key Biscayne, one-sixth part is rock-bound, one-tenth composed of drift antecedent to the present geological epoch, and the remainder sands winnowed out by the waves. Beaumont estimates that "one-third of the sea borders of the world is defined by the littoral cordon," *i.e.*, is shaped in outline by sands cast up or strewn along by the sea.

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in Boston Harbor which threatens to cross the main channel. Fortunately Congress has listened to the prayers of the Harbor Commissioners, and has provided for arresting its progress.

Shingle levees appear to me to be worthy of careful study, because they are the best natural measures of the power of storm waves, and I have made the dimensions of this one at Scituate a special subject, in order to ascertain to what height the *dikes*, required further down the beach, must be carried in order to prevent the overflows that now frequently occur.

The portion of the shingle levee which lies between Third and Fourth Cliffs is about four thousand three hundred feet in length, with a general elevation of sixteen feet above the plane of high-water, and a base of two hundred feet. It is composed of round and oval stones, those near the water line of the seaward side being the largest, and those upon the summit the most flattened. Paving stones are gathered from the lower portions of the outside, but upon the summit the average size may be stated at three and a half inches maximum diameter, and one inch thick in the middle.

The crest of the levee appears to the eye perfectly horizontal, and but slightly curved back from a straight line. The table of levellings given below, however, shows that there are depressions at either extremity, and that it is only the highest portion that is very near the horizontal for any considerable distance.

Longitudinal Section of Shingle Levee.

Datum=High Water of the Sea.

Distance in metres.	Height above mean H. W. of Sea.	Distance in metres.	Height above mean H. W. of Sea.	Distance in metres.	Height above mean H. W. of Sea.
0	14.32*	5.40	16 15	10.20	13.71
60	12.83	6.00	16.15	10.80	13.04
1.20	15.45	6 60	15.65	11.40	13.41
1.80	17.00	7.20	15.30	12.00	12.71
2.40	16 40	7 80	14.73	12 60	11.01
3 00	16.70	8 40	15.03	13.20	9 21†
3.60	16.77	9.00	14 29	13.20	13 21‡
4.20	17.10	9.60	13.71	13.40	22 41§
4.80	15.95				

* Foot of Fourth Cliff. † On Levee. ‡ On Bluff. § On Third Cliff.

Within the memory of persons now living in Scituate, the sea has once (during the Minot's gale) leaped over the depressed portions of this levee near its extremities, and the sea water has several times

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been seen oozing through in these places, but to no extent that could be injurious.

The height of this levee is greater than is usual among such formations, and its stones are larger. The maximum height given in our table is 17 feet above mean high water of the sea. Redman estimates the ordinary height of these formations in Great Britain at 6 to 10 feet.

The two slopes of our levee are very unlike in some respects; that toward the sea presents a series of berms,—miniatures of the great levee, thrown up by subsequent storms, * —while the leeward slope (toward the river) is a smooth hollow curve. (Figs. 56 and 57.) These are precisely the features we should expect to find in a structure which has resisted the storms of centuries. The fore slope should present the greatest resistance to the onset of the waves, and the rear slope the least resistance to the escape of overflowing water. I am reminded here of a short section of shore defence that I observed on the outer beach of the "*Pointe de Grave*" in the Bay of Biscay, which was constructed in the form of a *stairway*. The engineers informed me that it had resisted the sea better than anything yet devised. The waves of ordinary storms do not seem to weaken, but rather to strengthen the shingle levee. They cast up the windrows or berms, of which I have spoken, and thus prepare it to withstand more effectively the onset during violent gales.

In the following tables I give the elements for profiles of ten cross sections of our shingle levee, and a mean section from the higher and less disturbed portion.

* Redman and Coode in their papers read before the Inst. C. E. used the word "fulls" for these windrows or berms whcih mark the action of the recent storms.

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Sections of Shingle Levee.

	Section I. 120 Metres.		Section II. 240 Metres.		Section III. 360 Metres.	
	Distance in feet.	Height above mean H. W. of sea, in feet.	Distance in feet.	Height above mean H. W. of sea, in feet.	Distance in feet.	Height above mean H. W. of sea, in feet.
Fore Shore.	65.6	0.13	–	–	78.7	0.21
	59.0	2.33	–	–	62.3	4.51
	52.5	4.63	–	–	52.5	6.41
	45.9	4.93	65.6	1.60	45.9	7.31
	39.4	6.03	52.5	5.20	39.4	9.11
	32.8	6.43	36.0	7.80	29.5	10 17
	19.7	9.05	29.5	9.50	22.9	13 27
	9.8	13.45	19.7	8.83	16.4	15.17
	6.6	14.15	6.6	13.80	6.6	15.57
Crest.	0	15.45	0	16.40	0	16.77
Back Shore.	6.6	14.95	13.1	14.20	3.3	16.47
	19.7	12 85	26.2	9.60	16.4	13.87
	32.8	9.82	39.4	6.12	26.2	10 04
	45.9	7.72	65.6	2.80	36.0	6.70
	65.6	6.42	82.0	1.40	59.0	3 90
	98.4	4.52	98.4	0.70	68.9	4 00
	131.2	2.72	111.5	—1.30	85.3	3.00
	144.3	1.92	–	–	104.9	2.30
	154.2	1.12	–	–	118.0	—0.10
	164.0	—1.28	–	–	134.5	—1.42

NOTE.—The datum plane is mean High Water of the sea. The distances in metres are measured along the crest from Fourth Cliff.

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Sections of Shingle Levee.

	Section IV. 480 Metres.		Section V. 600 Metres.		Section VI. 720 Metres.	
	Distance in feet.	Height above mean H. W. of sea, in feet.	Distance in feet.	Height above mean H. W. of sea, in feet.	Distance in feet.	Height above mean H. W. of sea, in feet.
Fore Shore.	88.6	—1.56	–	–	–	–
	72.2	1.14	98.4	—2.50	–	–
	62.3	3.14	75.4	0.20	88.6	—2.80
	55.8	4.84	65.6	2.50	55.8	2.90
	39.4	7.04	55.8	5.10	49.2	4.50
	32 8	8.74	49.2	5.10	32.8	7.30
	29 5	9 82	36.0	7.40	22.9	8.00
	22.9	12.45	29.5	7.90	19.7	9.07
	13.1	12.85	19.7	9.38	9.8	10 90
	6.6	13 95	9 8	11.90	6.6	12.00
Crest.	0	15.95	0	16.15	0	15.30
Back Shore.	9.8	14.65	9.8	15.65	9.8	14.30
	19.7	12.55	16.4	14.55	26.2	10.60
	42.6	6.63	26.2	11.55	42.6	6.40
	75.4	3.86	32 8	9.12	75.4	2.40
	108.2	2.76	49.2	4 86	108 2	1.50
	141.0	—0.24	65.6	2.66	141.0	0 70
	157.4	—0.74	82.0	1.76	173.8	0.70
	164.0	—0.04	114 8	1.26	–	–
	183.7	—0.14	147.6	0.56	–	–

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Sections of Shingle Leves.

	Section VII. 840 Metres.		Section VIII. 960 Metres.		Section IX. 1,080 Metres.		Section X. 1,200 Metres.	
	Distance in feet.	Height above mean H. W. of sea, in feet.	Distance in feet.	Height above mean H. W. of sea, in feet.	Distance in feet.	Height above mean H. W. of sea, in feet.	Distance in feet.	Height above mean H. W. of sea, in feet.
	-	-	-	-	-	-	114.8	—5.00
	-	-	-	-	-	-	88.6	—2.00
	98.4	—3.00	-	-	124.6	—4.56	65.6	1.20
	82.0	—1.10	-	-	108.2	—3.66	59.0	2.90
	65.6	2.40	12.14	—4.50	75.4	—0.16	55.8	4.10
	59.0	4.83	88.6	—1.20	68.9	1.24	49.2	4.40
	49.2	5.00	68.9	1.20	55.8	4.72	42.6	5.40
	42.6	6.70	55.8	4.50	39.4	6.14	39.4	6.70
	32.8	6.91	42.6	6.40	22.9	7.14	26.2	7.01
	22.9	8.80	29.5	6.64	13.1	10.34	16.4	8.50
	9.8	11.60	6.6	12.20	9.8	10.94	6.6	10.70
Crest.	0	15.03	0	13.71	0	13.04	0	12.71
	6.6	13.70	9.8	13.30	6.6	12.80	6.6	12.30
	16.4	11.10	29.5	9.60	16.4	11.40	16.4	11.20
	32.8	8.11	42.6	7.50	29.5	9.11	49.2	7.40
	49.2	5.00	75.4	4.87	55.8	5.74	82.0	2.88
	72.1	2.30	108.2	2.90	72.2	3.94	114.8	1.20
	98.4	1.70	141.0	1.00	104.9	2.04	147.6	0.50
	127.9	0.60	173.8	0.70	121.4	1.64	180.4	—0.70
	164.0	0.60	-	-	154.2	1.34	-	-
	-	-	-	-	186.9	0.44	-	-

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Mean of Sections I, II, III, IV, V, VI. (Fig. 8.)

	Distance.	Height above mean H. W. of sea, in feet.	Slope.
Fore Shore.	90 feet,	—1.82	0.133
	80 "	—0.49	0.199
	70 "	1.50	0.107
	60 "	2.57	0.279
	50 "	5.36	0.162
	40 "	6.98	0.163
	30 "	8.61	0.187
	20 "	10.48	0.243
	10 "	12.91	0.309
Crest.	0 "	16.00	0.000
Back Shore.	10 "	14.84	0.116
	20 "	12.50	0.234
	30 "	9.50	0.292
	40 "	7.12	0.246
	50 "	5.60	0.152
	60 "	4.52	0.108
	70 "	3.72	0.080
	80 "	3.06	0.066
	90 "	2.66	0.040
	100 "	2.27	0.039
	110 "	1.60	0.067
	120 "	1.44	0.016
	130 "	0.89	0.055
	140 "	0.87	0.002
	150 "	0.54	0.033
	160 "	0.01	0.053

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Caland constructed the great dike of West Capelle under the conviction that the action transmitted by the shock of the waves should vary with the square of the height of the water covering the talus, and that the base of the fore slope of a dike should be in proportion to the square of the height.* If I take the dike of West Capelle as the standard, I obtain for the Scituate levee the slope of 4 : 1. Our levellings give 3 : 1 near the crest, and 5 : 1 as an average for total slope. As far as my observations have gone—and this is not so far as to admit of my speaking with entire confidence—the fore slopes of shingle levees are constant, *i.e.*, the base varies with the first power of the height. Near the crest the slope is greatest, usually 3 : 1 where undisturbed, but the total slope is 5 : 1. When I visited the grand dike of Petten in 1868 I found Mr. Conrad *pitching* the storm belt with basalt blocks at 3 : 1 and 5 : 1. From his history of this great work,† I find that these slopes for stone-pitching are always adopted irrespective of the total height.

The leeward slope for different sections is very nearly the same from point to point except near the base, where it is affected by different elevations of the river bed upon which it lies. It is probably the curve of least resistance for the material employed. It sometimes approximates quite closely the cycloid, and it always has an aproning to protect the base. If it were steeper, the fall of overflowing water would excavate the marsh at the foot and endanger the whole structure; if it were less inclined, there would not only be a waste of material, but in the event of a rapid succession of overleaping seas, the accumulated waters might react and burst through the crest. Dikes and breakwaters are usually built with very steep rear slopes, and the larger part of the disasters which have befallen these structures, has resulted, not from the force of the sea upon the fore slope, but from the fall of overleaping seas upon the inside works. The shingle levee may fulfil many purposes in nature besides that of defence, but viewed simply as a bulwark it discovers a wonderful economy.

Below Fourth Cliff the shingle levee continues for a considerable distance, but gradually loses its distinctive character and merges with the sands, which seem to have preceded all other material in the march southward. In the year the communities about the North River attempted to cut a new outlet in this portion of the beach, using at first hand labor, but ultimately employing a dredging

* *Essai sur les Travaux de Fascinages par U. N. Kümmer.*

† Verhandeling over de Hondsbossche Zeeweering door J. F. W. Conrad Ingenieur de 1ste klasse van's Rijks Waterstaat.

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machine. The bottom was removed to a depth of 6 feet below the marsh level, but not to the low water of the sea. Contrary to expectation, the water, instead of flowing seaward, rushed in towards the river—Fourth Cliff Bay being, as we find from our observations, below the high water level of the sea. The influx was at times very strong, but seemed quite powerless to enlarge or deepen the trench through the firm and unctuous soil of the marsh—to use the expression of the workmen, "*the stream wouldn't gull.*" Heavy weather came on soon after the work of the dredging machine ceased, and the waves drove in masses of sand and stones, which soon choked up the pass. In course of time a shingle levee formed across the inlet, and rose to the height of 10 feet above the high-water plane of the sea. I give a section of this new formation, in which no decided berms appear.

Cross Section of New Levee.

	Distance from Crest, in feet.	Elevation above mean H. W. of sea, in feet.		Distance from Crest, in feet.	Elevation above mean H. W. of sea, in feet.
Fore Slope.	137	—7.6	Rear Slope.	0	10.9†
	102	—4.6*		20	7.3
	72	—1.8		33	5.3
	49	1.5		59	3.5
	39	4.0		125	1.8
	33	5.2		192	—0 3
	23	6.9		256	—1.7‡
	13	10.5		-	-
	6	10.7		-	-

NOTE.—The average fore slope, above the plane of high water, is 5 : 1; while the greatest inclination, (near the crest,) is 2¾ : 1.

* Half tide or mean level of sea. † Crest. ‡ H. W. plane of river.

I glean one very curious fact from those employed in opening this channel, viz., the original bank of shingle was found to extend downwards only to the surface of the marsh which was not sensibly depressed beneath its weight. I infer that, as Fourth Cliff wears away the whole beach falls back, and the present banks of sand and shingle are really superimposed upon ancient meadow lands or river channels. The marshes are not floating bogs like the *koogs* of Denmark, or liable to slump down after enclosure, like the *polders* of Holland. The newly formed levee, across the mouth of the artificial outlet, exerts a pressure of over 1,200 lbs. to the square foot upon the marsh beneath its crest, and the weight of the original bank, as far as I can

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judge, was over 1,700 lbs. to the square foot under the crest. I have allowed in these estimates 25 per cent. for voids. Old rubble breakwaters, that have been shaken down by the waves to a state of repose, occupy still a space 25 to 30 per cent. greater than the rock *in situ*.

Some shrinkage will no doubt take place after drainage is effected, but this will not, I think, exceed 10 to 12 per cent. If the *water-table* is dropped four feet, I shall expect the marsh surface to sink about six inches.

Shingle Levees Elsewhere.—My assistant, Mr. H. L. Marindin, has recently examined the levee near Chelsea, Massachusetts, the southern portion of which is more exposed to the sea, and therefore the highest, reaching an extreme elevation of 14.13 feet above mean high water. The fore slope of this portion has an average inclination of 5 : 1, and an extreme, near the crest, of $2\frac{3}{4}$: 1. The exposure is only to the south-easterly quadrant, and the shallow flats which extend a long way to the seaward break the force of the sea. The longitudinal profile of this levee shows a decline of height as the observer moves to the northward, reducing the angle of exposure, and falling under the shelter of Nahant. This levee is without distinct berms, and its rear slope is 3 : 1 above the apron.

The highest shingle levee in the world is Chesil Bank, on the south coast of England, in a situation peculiarly exposed to the violent seas that rush into the Channel. Its height varies from 23 to 43 feet along a distance of 10 miles. The inclination of the fore-slope in the most perfect part of this levee is 5 : 1.

Upon the borders of the Bay of Audierne, in Brittany, there is a shingle levee nearly eight miles in length, whose average height is 16 feet,—the same as our levee at Scituate, and like the latter, its seaward face is a series of berms.* The fore slope is 3 : 1. "The shingle levee," says Beaumont, "when viewed as an isolated phenomenon, merits but little attention, but in its relations to other phenomena we recognize that it has a great influence upon a crowd of important facts."

Perhaps the most singular freak of the sea in the way of dike building is to be found upon Salt Key, one of the smallest of the Bahama Islands. Here occurs a nearly perpendicular wall, about 12 feet high, constructed wholly of *conch shells*, nearly all of them per-

* A sketch of this levee is given in Beaumont's "*Geologie Pratique*," page 225. In another part of the same book mention is made of the three Druidical *men-hir* upon the little island of Quemenès, off the coast of Brittany, followed by a statement that this island is less than 33 feet above the ocean, and that if it had ever been traversed by the sea during the past 2,000 years the *men-hir* would have been upset by the washing away of the soil in which they stand.

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fect. One might suppose from the uniform height of this wall, and its perfect alignment, that it was a work of art—except that to build a "dry wall" of conch shells would rather puzzle human ingenuity.*

The dikes along the coasts of Europe may be said to furnish limiting measures of the heights of overflows not wholly local in their significance. Until a comparatively late period the sea dikes in Holstein and Schleswig were raised but 10 feet, and in Holland but 10 to 13 feet above ordinary high-water mark. Modern engineers, however, have carried these works to greater elevations. On the Schleswig coast 18½ feet above the highest spring tides is regarded as entirely safe.† On the Dutch Coast, after a recorded experience of four hundred years, the grand dike of Petten has been carried up to 21 feet above ordinary high water,‡ and upon the Mediterranean shore of France 16½ feet is proposed for new works.§ As the injury suffered by sea dikes has been principally due to the rush of water down the landward slopes during overflows, it has been deemed prudent to raise the crests of the most exposed and important works to the extraordinary heights I have stated.‖

Breakwaters do not furnish what I have termed "limiting measures," because many of them have been built with the expectation that storm seas would leap over them, while others have been carried high for the sake of *weight*. Although most of the breakwaters have been built in situations already partially sheltered, there are instances where they have been more exposed than the adjacent coasts.

Sand Beach.—Further down the Scituate beach the stones gradually give place to sand, and the shore no longer reflects the action of the sea alone, but is diversified by dunes blown up by the winds. There are occasional points where traces of overflow appear, and I give the section of one of the slue-ways formed by the Minot's gale, and traversed by the sea at least once a year since that memorable storm:—

* Reported by myself in 1867.

† Testimony of Capt. Carstensen, Dike Inspector, cited by J. Paton, M. Inst. C. E.

‡ From a diagram entitled "*Scituate der Pettimer Zeewering*," furnished me by J. F. W. Conrad, engineer of the *Waterstaat*.

§ *Ponts et Chaussées, Départment de l'Herault*, report of the Engineer in Chief.

‖ The highest dike that I call to mind is that of West Capelle, over 26 feet above the tide.

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Section from Upland to Ocean, crossing North River at Slant Spar (Fig. 10).

Distance in feet.	Elevation in feet.	Distance in feet.	Elevation in feet.
0	4.34	478.	—3.6
36.	1.72	493.	—2.9
85.	0.93	508.	—2.9
125	1.44	523.	—2.9
141.	1.19	538.	—2.9
243.	0.37	554.	—0.92
262.	0.72	590.	1.08
328.	—0.92	656.	2.89
343	—2.9	934.	5.05
358.	—3 0	1,000.	5.50
373.	—4 5	1,066.	6.78
388.	—4.9	1,197.	8.76*
403.	—4.2	1,262.	6.68
418.	—4.2	1,331.	4.94
433.	—4.2	1,387.	0.95
448.	—3.9	1,426.	0.71
463.	—3.9	1,505.	—4.00

NOTE.—Datum=High water plane of river, June 23, 1870=1.70 feet below mean high water of sea.

*=7.06 above mean high water of sea.

The maximum height of this slue-way is seven feet; this may be regarded as the measure for annual overflow.

Professor Whiting, in his excellent paper on Provincetown Harbor, published in the Coast Survey report of 1867, says (speaking of the outside coast), "Already the breakers have dashed over the narrow strip of sand-beach at what I term the oblique section," which has an elevation of fourteen feet above high water of the ocean. The exposure at Fourth Cliff is about the same in north-east gales as that of the outside shore of Cape Cod.

I have given in Fig. 10 a profile plotted from the preceding table, because it illustrates so well the double action in overflow—the violent dash against the seaward face, and the flowing down on the opposite slope. On sandy shores a mound thrown up by the sea can nearly always be distinguished from one due to the wind; in the former the steeper slope is *seaward*, in the latter *leeward*, so that an overflow reverses the order of the slopes found in a dune.

In running water (in the bed of a river for instance) the sands take the form of flat dunes, which correspond in the order of their slopes with those on land.

With no desire to involve myself in the discussion of wave

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theories, I must state one point because of its bearing upon my general subject. The positive and negative, or *crown* and *hollow* portions of a storm-wave are of unequal heights, so that the rise above the sea-level (plane of equal volumes) is considerably greater than the fall below. Many shoals, whose depths given upon our charts are less than half the range of ordinary storm-waves, have never been seen exposed in the trough of the sea. Some years since a heavily-laden ship, drawing about eighteen feet of water, was driven by an easterly gale across several of the Nantucket shoals, upon which, according to our maps, the depths scarcely exceed eleven feet. She struck heavily many times, but the leadsman never called less water than the chart indicated. Standing upon the beach during a heavy storm, one rarely sees, as the waves retire, much more of the strand than in ordinary weather; and Robinson Crusoe's thrilling account of his race for life across the floor of the ocean, during the recoil of the sea, disturbs our confidence in him at the outset of his narrative.

General rise.—The *mean-level* rises during storms from seaward, and this must always be taken into account in projects for dikes and dams. This *general rise* can best be measured by observing the height of the water's surface in sheltered coves and harbors.

Major Graham's report on Cape Cod Harbor shows, from tidal observations between 1833 and 1835, that a twenty-four hours' gale from the south-east (*i. e.* directly into Massachusetts Bay) causes a general rise of 3.33 feet. The coping of the United States dry dock at Charlestown was designed to be above the highest tide, and was placed 4.69 feet above mean high water. The sea has actually risen 0.4 above the top of this coping once during the past twenty years. If we grant that the storm-rise is affected by the configuration of a harbor or bay in no greater degree than the ordinary tide, we must apply a correction to the Dry-Dock rise of nearly ten per cent. in order to reduce it to its proper proportion for the outside coast. We have then four and a half feet for the *general rise* during violent storms. I do not think it necessary to go back more than twenty years in estimating the height to which the sea is likely to rise, because there is no economy in providing for contingencies which do not present themselves more than once in a lifetime. In Holland, where the lives of thousands depend upon the security of the dikes, the works are only provided for ten feet general rise, although the tradition of the Cimbrian flood is over forty,—and the Deluge greater yet.

Dean's history mentions that the sea has been known to flow over the isthmus which divides Scituate Harbor from the North

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River, and I am informed that during the Minot's gale the rush over this place was so great as to sweep away fences, &c. I had not time to run a line of levels over this isthmus, which I regret, because I think it would have given an excellent measure for "*general rise.*" The overflow in the Minot's gale, to which I have just referred, injured the lands to such an extent, that it was not until the third season after, that the English grass recovered its former luxuriance.

To recapitulate: the heights to which the sea has run upon the outside shore above mean high water of the sea are,—

In the long past, ...	17 feet.
In the heaviest gale observed, ...	13 "
In winter storms, ...	7 "

The beach should be protected against a fourteen feet run of the sea. We have found between the Fourth Cliff and the South River junction only five slues which fall below this standard height, and these we have sectioned. The point of the beach near the mouth of the North River is generally low for 1,200 feet, but will afford, I think, no source of trouble for many years.

The interior dams must be at least three and a half feet, but need not (if perfectly sheltered) exceed four and a half feet above the mean high water plane of the sea, to escape overflow from the "*general rise*" during storms.

The bench of our survey is situated on the right bank of the river, nearly opposite Slanting Spar. It is within a circle cut upon the highest point of a boulder, which boulder may be distinguished from other rocks by its having an iron ring-bolt on one side. This bench is 1.23 feet above *mean high water of the sea* (as computed).

Mouth of River.—During the last century the river mouth has been forced to the southward by the advance of the beach a distance of nearly one mile, and since our survey of 1858, about 1,000 feet. A beach of small shingle now stretches from the coast south of the embouchure, and overlaps the beach of which I have been speaking, so that the river makes a sharp turn just before issuing upon the sea.

Between the mouth of the river and White's Ferry the stream has been injured by overflows from the sea, which have not only rendered the channel more shallow but made it narrower than formerly, the material of the beach being much of it too heavy for the ebb-current to remove, and the opposite bank of the stream too firm to yield in due proportion.

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The shoalest place in the river is in the vicinity of the slue-way of which we have given the section in Fig. 10. It is encumbered with banks, and the average depth of a pathway 100 feet wide, along the line of greatest depression, is only five feet at ordinary high water. Tradition says that nearly a century ago the mouth of the river was at this point, and that since the river moved on there have remained here impediments to navigation. However this may be, the Minot's gale re-opened a track over the beach, and poured into the stream a mass of gravel and shingle that completed the ruin of the river as far as navigation is concerned. We have made a close survey of this portion of the stream, and deposited a chart of it at the office, bearing the names of the observers.

Character of the Marshes.—Relative to the constitution of the soil I shall venture to say very little, because the subject is beyond my ken, but this little will be said with the hope of eliciting further information of a better description.

The surfaces of these marshes are nearly horizontal and lie at the level of high tides. To my mind they are not to be accounted for under the term "glacial paste" or "river debris." I do not regard them as detritus from the interior, but, in the main, as products of the waste of the coast. I have found them in sheltered coves or angles of the shore in high countries, in low countries and in islands far from the continent, wherever the coast yields to the dash of the sea.

When a headland crumbles down in the attack of the waves the materials are assorted almost immediately: the coarse sand, gravel and stones are strewn along to form the littoral cordon, but the finer materials are held in suspension till chance gives them the opportunity to settle in sheltered places, perhaps under the lee of the cordon itself. Even upon coasts where the shores are already composed of sands as in North Carolina, the work still goes on; the sands are ground up by the waves, and borne into the lagoon by the current. I have observed at Hatteras Inlet that after severe gales the sea along the coast becomes milky with fine quartz sand which the currents at the inlets bear into the sounds and there relinquish to form banks which in course of time are covered with sea-grass. The coast line falls back steadily and the lagoons fill up preceptibly. The Hatteras beach has probably been thrown up by the sea along the *breaker line* of a bank (the submerged prolongation of the continent which here has but a slight inclination towards the ocean) and as the coast falls back the cordon is still supplied with coarse material from the underlying ground, while the waves find, ready made, much fine material with which to fill up the lagoons. I have

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selected Hatteras for my illustration because it is an extreme case. The sluggish rivers do not render turbid this portion of Pamlico Sound, and the ebb current at Hatteras Inlet is usually very clear. I do not of course mean to say that the outside coast alone supplies shoal building material for all parts of this interior sea, because I have often seen the waters flowing from Croatan very much laden with sediments.

When my friend Whiting shall have executed his promised map of the "completed contours" of the half destroyed headlands of the New England coast, you will perhaps discover adequate sources of supply for many shingle levees, travelling beaches and fertile marshes, without drawing upon your imagination for visions of other lands that have long ago sunk into the sea and left no sign.

The fertile polders of Holland which are supposed to have been formed directly or indirectly from the deposits of the Rhine, are underlaid with peat, but the new and more fertile marshes of the Humber which can have no similar origin are without peat, and are seventy-six per cent. *fine sand* "with only four per cent. organic matter."* Professor Phillips in his geology of the Yorkshire coast says: "The materials which fall from the wasting cliffs between Bridlington and Kilnsea, are sorted by the tide, according to their weight and magnitude; the pebbles are strewed upon the shore, beneath the precipice from which they fall; the sand is driven along and accumulated in little bays and recesses; whilst the lighter particles of clay are transported away to the south, making muddy water, and finally enter the great estuary of the Humber, and enrich the level lands under the denomination of warp." The term "warp" used in the above quotation refers to the practice of building submersible dams for the sake of catching sediments and forming thus new lands—the process is called "warping" and is employed also in the Netherlands.

I think that the popular notion that the deep sea is being generally filled up with material torn from the continent is erroneous. The facts seem rather to indicate that it is the sheltered indentures of the coast that are receiving deposits.† There are indeed evi-

* "On reclaiming land from seas and estuaries, by James Oldman, M. Inst. C. E."

† Not to speak too critically, the form of a profile of soundings extending from the continent is this: A long slope from the shore line to the 100 fathom curve, then a rather sudden pitching down to the floor of the ocean. The distance to which the long slope extends from the coast varies in different profiles, but the *depth* at which the sudden pitching off commences, seems to be the same not only in many profiles from our own shores, but from the opposite shores of the Atlantic. Perhaps this long slope measures the depth of itation due to meteorological causes.

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dences that the ocean proper is, in many localities, pushing its way into the continent. It is particularly noticeable that gulfs and bays which open in the direction from which heavy gales are prone to blow, are extending without any diminution of average depth along their axial lines, except where rocks resist for a while the wear of the sea. As an example, and a good one, because resting upon positive knowledge, I offer the case of the Gulf of Gascony in the neighborhood of St. Jean de Luz, where repeated surveys show that the submerged contours are falling back and the bay actually extending and deepening. The material scoured away is ground up fine by the waves, cast upon the beach, and finally blown away in dunes towards the interior.* The bight of Cape Cod Bay below the Plymouth entrance bears every trace of an encroaching sea. The water is bold close in shore, so that a man-of-war may ride at anchor within what was probably the base of the high hill whose remaining portion bears the name of Peaked Bluff. The waves have carried none of the material seaward (of this we are sure from the character of the bottom), but have swept it along shore to the eastward, the fine sands to be formed into dunes, and the shingle to be moved on and accumulated until it shall become equal to the protection of the shore by resisting the onset of the sea.

I have not, in our repeated surveys, seen the slightest evidence that the material of the falling bluffs of Boston Bay are borne out to sea. I think the harbors and coves have received it all.† The ebb tidal currents seem to have kept the channels sufficiently free and may have carried out to sea some very light substances, but we do not find them deposited there.

I am inclined to think, with Admiral Davis, that the waves "eject or repel" the debris of the continent which falls within their domain, that there is no permanent deposit or rest for such materials till shelter is reached; I differ however from this writer in respect to the carrying powers of the flood current.‡

Mr. A. Savary, an engineer residing at East Wareham, has written me an able and very interesting communication concerning Buzzard's Bay, in which he gives me the results of observations—some of them stated numerically, which show that the sheltered basins at the upper end of the bay are filling up with sand and stones torn from headlands (below) which are wasting under the

* From a lithograph copy of a report furnished to me by the author, Bouquet de la Grye, Hydrographic Engineer of the W. Coast of France.

† I must again refer you to the letter of Professor Agassiz, quoted in the introduction to this Report

‡ See memoir of Lieutenant Chas. H. Davis, Fourth Vol. (new series) Am. Acad. Arts and Sciences, also Smithsonian Contributions of 1851.

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action of the waves during southerly gales. Some of these basins, he says, are used for planting oysters, and from his own experience states that after a gale the oysters are always found higher up the stream. He however attributes this movement altogether to the flood current * and makes it dependent upon the depth of superincumbent water—a conclusion that seems to be opposed to well established laws of hydrodynamics, although I am aware that some English engineers of eminence (among them Mr. Calver) still insist upon making *weight* an element in the friction of running water.

The views I have entertained relative to the restoration to the continent of all the material washed from its bluffs and headlands by the sea, must be modified when we come to consider islands. Where these are crumbling down under the action of the waves, we usually see a loss upon the windward shore, and a reappearance of the material upon the leeward side. Sometimes we find two hooks extending leeward from either end of a wasting island, as in the case of Nantucket, and these hooks, in other cases, unite under the lee and enclose lagoons, which ultimately become, perhaps, marshes. High islands may thus gradually be converted in low atolls (if I may use this term), which occupy more than their original share of the ocean bed. There are, however, many cases where the wasted material does not reappear, most prominent among which, is the familiar instance of Helgoland, a lofty island which in the eighth century was a thousand times its present area.

To return to the North River Marshes, I must confess that there is one feature in them which is more characteristic, I think, of river deposits than of mere tide lands. I refer to the natural levee along the river's brim, which is, perhaps, one foot more elevated than the marsh further back. In many places this slight elevation enables a heavy growth of clover to exclude the meadow grasses, and bears witness to the fertility of the soil redeemed from the sea.

Since writing the above, I find from a conversation with Professor Shaler that he has been for some time engaged in a study of what he appropriately calls "*the pocketing of sands*" along our coast. He points out several localities in which this operation can be traced, and conceives that the lower harbor of Boston is just beginning to receive supplies in this way.

Value of Tide Lands.—The unimproved salt marshes of Massachusetts, under average conditions of distance from market, and

* Very much the same view that was expressed by Lieutenant Davis.

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accessibility during the mowing season, are worth eight dollars per acre. In Delaware and New Jersey, similar marshes, held formerly at about the same price, have been properly diked, and become equal in fertility to the prairie land of the West, and in these States many farmers, investing their capital in such improvements, have seen it restored tenfold. I know a district in Holland, newly drained, that has become the residence of a large community of farmers, who live in comfort and with every indication of health and happiness, although the average area to the individual is only one half acre.

Tides.—Dean's History, as we have seen, gives "3 to 5 feet" as the rise and fall of the tide at North River Bridge forty years ago, and I am inclined to accept the statement, not only because the author is reputed to be careful in such matters, but also because the recollections of Captain Tolman, and other persons in this very intelligent neighborhood, confirm it. In the present obstructed condition of the river the range of tide at North River Bridge varies from 0.8 to 1.5 feet, and the range does not now exceed these figures at any point above White's Ferry, near which the modern overflows have occurred. The obstructions act as weirs, over which only the upper portion of the tide flows. The highest place in the river bed along the thread of the channel is 1.60 feet below the mean level of the sea, and upon this weir the tide does not rise to the high-water level of the ocean, because of the rush into the reservoir beyond, which does not get filled in the short time allowed.

The following table exhibits the times and heights of a low neap tide:—

Tides of North River.

Station.	High Water, Interval after Moon's Transit.		Range of Tide, in feet.
	h.	*m.*	
Cape Cod Bay,	XI.	X.	7.7*
Station 1st,	XI.	XV.	4.7
Station 2d,	XI.	XXX.	3.7
Station 3d,	XI.	XL.	1.7
Rogers' Wharf,	XI.	XLIV.	0.8
Little's Bridge,	XIII.	XLII.	0.5†
Union Bridge,	XIII.	LIX	0.6
North River Bridge,	XIV.	XXX.	0.8

* Spring range = 10.58. † Spring range = 1.1.

The obstructions in the lower reach of the river do not protect the marshes from an inundation on the occasion of a great *general rise*

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outside, because, after the river mounts two or three feet above ordinary high water its section becomes very ample all the way from the sea. But the obstructions play their part in preventing the prompt relief from inundation, since, with the subsidence of the *general rise* outside, the sections at the obstructions return to their ordinary dimensions and the outlet is choked. What is true of inundations due to "general rise," is also, in a measure, true of every spring tide. The high-water volumes flow easily up the river into the Fourth Cliff Bay, but are so delayed that when they would return to the sea they find that the fall of the tide has left but a contracted section in the lower reach of the stream, and, although this becomes the scene of a torrent during the low stages of the outside tide, the relief is not afforded for several days. It is especially at the season of hay-cutting on these meadows that the prolonged inundations become injurious; and Captain Tolman informs me that an increase in their durations has been observed, and much commented upon by persons whose memories go back to better times.

Of course the order of the tidal currents is very much affected by the tendency of the obstructions to limit the supply of tide-water in the reservoirs during the rise, and pond it back during the fall. The flood current, although it does not begin to run in over the shoals until it lacks but about two hours and a half of high water, continues about one hour and a half after the tide has begun to sink. The ebb current continues about eight hours, and runs most rapidly about the time it is low water in the sea. You will perceive that the flood and ebb, the one pouring in at high water, the other struggling out at low water, cannot be properly compared by their durations alone, but their volumes must be considered since the sections are unlike. Here is a case where "Prof. Peirce's criterion" is not applicable, for obvious reasons, and it becomes necessary to compute the fresh-water supply from actual gauging. This computation is given in the following table from observations over a short reach just below the shoals:—

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Mean Height of Surface.	Time, 23d June, 1870.				Mean Section.	Mean Velocity per second, in feet.	Volume per second, in cubic feet.	Period, in seconds.	Volume, in cubic feet.
	h.	m.	h.	m.					
0.9	5	34	6	00	705	0.4	282	1,560	439,920*
1 3	6	00	7	00	792	1.6	1,267	3,600	4,561,200†
1.7	7	00	8	00	879	2.6	2,285	3,600	8,226,000
1.6	8	00	9	00	857	1.6	1,371	3,600	4,935,600
1.2	9	00	9	15	770	0 2	154	900	138,600
Inflow, ...									18,301,320
0.9	9	15	10	00	705	0.8	564	2,700	1,522,800
0.6	10	00	11	00	640	2.4	1,536	3,600	5,552,960
0.3	11	00	12	00	575	3.3	1,897	3,600	6,829,200
0.2	12	00	13	00	553	3.3	1,825	3,600	6,570,000
0.1	13	00	14	00	532	3.1	1,649	3,600	5,936,400
0.05	14	00	15	00	522	2 9	1,514	3,600	5,450,400
0.0	15	00	16	00	510	2.9	1,479	3,600	5,324,400
0.10	16	00	17	00	532	2.2	1,170	3,600	4,212,000
0.5	17	00	17	29	618	0.6	371	1,740	645,540
Outflow, ...									42,043,700

* Mean L. W. Section 510; mean H. W. Section 879.

† The height of surface is referred to low water, (4.6 below "Primary Bench.")

Effect of a Dam.—From the above table the river discharge may be computed to be 11,871,190 cubic feet during six hours, and this quantity includes any reservation from the preceding higher tides. Now the area of the river surface above the gauging place, and below the North River Dam, is 32,920,470 square feet, exclusive of tributaries and creeks. If upon the day of gauging a dam had been thrown across the stream, the average rise of the river behind it would have been 0.36 of a foot in six hours. As the area of the river surface would be reduced by drainage, the average rise, under otherwise similar circumstances, would be slightly augmented.

The figures I have given are true for the period of my observations, but of course vary with the rainfall at different seasons. My acquaintance with the river is too short to permit me even to conjecture upon what date in the spring the river becomes drainable. On Sept. 29th, just before the beginning of the rains, after the long drought of the past season, my aid, Mr. F. H. North, gauged the river again at Little's Bridge, at the head of Fourth Cliff Bay, and found the flood and ebb currents of nearly equal duration, and the

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density of the water as high as 1.017 on the last of the ebb. In effect the stream had become an arm of the sea, without any perceptible rise due to fresh-water.

During the coming winter and spring, opportunities will be offered for examining the conditions of the river under the circumstances most opposed to drainage, and I suggest to the marsh owners an occasional repetition of some of the observations I have detailed in this report—that the whole scheme may be reduced to figures, and not a dollar spent that can be saved, or saved at the expense of success.

The removal of the shoals from the lower reach of the river is the obvious remedy for all difficulties of discharge, but the depth to which the dredging should be carried ought not to be decided upon before observations in the wet season are made. Deepening to the level of mean low water of the sea will be the utmost that can become necessary, and I hope that something even may be saved of this.

In addition to the observations which form the basis of the tide-table given above, we have half-hourly records of the rise and fall at stations simultaneously occupied, so that we can follow all the tidal phases from the sea to the North River Dam. I am obliged to omit, however, these details, because they are too voluminous for this report, and would require long explanation; but I shall venture to comment upon them briefly, to show their practical bearing upon the engineer's project.

I conceive that the engineer, in deciding upon the dimensions of his sluice-gates, may find it necessary to compute the variations of the slope and a study of the progress of the tidal phases will be his best resource. A gate closed upon a stream produces an effect like that of the rising tide at slack water, and the rise due to the closure is propagated at the same rate (essentially) as that of the tide. In a similar way, the depression caused by the opening of a sluice-gate falls back like the tide. With the North River at the level we found it, the rise on the closure and the fall on the opening of a sluice-gate at White's Ferry, would affect Fourth Cliff Bay in about one hour, the neighborhood of Little's Bridge in one hour and fifty-eight minutes, and the neighborhood of North River Dam in two hours and forty-six minutes. The duration of rise or fall would everywhere be equal to the time of closure or opening, so that at North River Bridge the water would sink for two hours and forty-six minutes after the gates were closed, or rise two hours and forty-six minutes after the same were opened. Fourth Cliff Bay

* An indispensable computation, if freshets are to be provided for.

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performs the function of a reservoir, and the sluice-gates should be placed as short a distance below as other circumstances will admit.

The marsh owners, both at Scituate and Marshfield, have wisely selected Clemens Herschel, C. E., to draw up plans of construction.

General Conclusions relative to the Projects of Reclamation.

First. The marshes of Green Harbor River may be drained by the construction of a sluice-dam at Turkey Point without unusual precautions or expense, but not without injury to the present facilities for navigation below said point.

Second. The North River marshes can be drained by constructing a sluice-dam at White's Ferry, provided the present obstructions below are removed by dredging; and provided also, that dikes are carried across the "slue-ways" of the beach, to the height of thirteen feet above mean high water of the sea.

Third. The dams, to escape overflows from the "general rise" during storms, must be carried at least four and a half feet above mean high-water of the sea.

Fourth. The marshes, after drainage, will not sink or shrink more than twelve per cent. of their elevation above the water-table.

Personal.

In the prosecution of my physical surveys in this section, during the past season, I have been assisted by volunteers from the Massachusetts Institute of Technology. To Mr. Hoyt (instructor), and to Messrs. Pike, Stone, Howland and Curtis (students), whose admirable training at the Institute fitted them for immediate usefulness, I am much indebted for the accuracy of my observations, and for the rapidity with which my work was performed.

My aid, Mr. F. H. North, commenced this season his study and practice of surveying, and served me both upon the Atlantic and Pacific coasts, with an energy and good will, that afforded me great satisfaction.

* * * * * * * * * * *

HENRY MITCHELL,
Chief Physical Hydrography, U. S. C. S.

To Prof. Benjamin Peirce,
Superintendent U. S. Coast Survey.

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REPORT OF PROF. WHITING.

PROFESSOR BENJAMIN PEIRCE, *Supt. U. S. Coast Survey.*

DEAR SIR:—In fulfilment of your instructions I have had made under my personal supervision, by Mr. O. H. Tittmann, of the U. S. Coast Survey, a survey of North River, in Plymouth County, Mass., including the upper reaches of the river from the limits of the former shore survey by Assistant A. M. Harrison, to the head of tidewater.

The importance of a complete survey of this portion of the river was first brought into notice by the action of the State Board of Harbor Commissioners in connection with the proposed scheme for the reclamation of the marshes which occupy the valley through which this river flows.

Your orders directing a coast survey party to execute this work, not only furnishes the desired data as a basis for the reclamation of these marshes, but also completes a section of important coast topography, and gives the necessary data for determining the relative value of this river as a navigable water.

In the comprehensive report of Prof. Henry Mitchell, Chief of the Physical Hydrography of the Coast Survey, he has solved the problem of the practicability of the drainage of the marshes of this river. His survey of the lower reaches of the river from its opening through the outer beaches to the enlarged section, or basin, above the artificial bar, which he has so elaborately determined, has covered the ground of the physical character and condition of this stream, and leaves but little to report in connection with my own survey of the upper portions of the river, except the simple statement of topographical details, and to present my maps which have been made upon a larger scale, $\frac{1}{5000}$, than that of our ordinary coast survey field work, as a basis for a scheme for the drainage of the upper marshes, and of improvement by shortened reaches and corrected bends in the pathway through these marshes, of the main channel of the river.

In connection with the general subject of my survey, I deem it

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my duty to report to you such facts and opinions as have come to my knowledge, bearing on the question of the conversion of North River from its natural condition as a tide-water stream, open to navigation, and once the seat of valuable ship-yards and some commerce, to a closed stream, from which all connection with other ports and waters by way of its channel and outlet to the ocean is essentially cut off.

Several questions present themselves for consideration in connection with the proposed change in the character and function of this river, viz.:—

First. The value of the inlet as a harbor, of the river as a navigable and commercial water, and of the marshes of the valley for agricultural purposes *in their present state.*

Second. The probability, by any natural causes and effects, of the river again becoming navigable, or any material change for the better taking place in the character and condition of its marshes.

Third. The practicability and economy of improving the inlet and the channel of the river so as to render it navigable, and its value for the purposes of maritime commerce and ship building, should this be done.

Fourth. The practicability and economy of shutting out tide-water, and the value for agricultural purposes of the territory thus reclaimed from salt marsh to fresh drained meadow.

In considering the first question named, it will be seen that the mouth of this river opens into the central part of Massachusetts Bay, and upon a straight and unprotected shore, exposed to the full sweep of north-east, east and south-east storms, with no indenture or headland to form any local shelter.

Owing to the limited extent and volume of the waters of North River its inlet is, and must ever be, of small capacity, and subject to change in width and depth by the action of storms upon the sandy bar and beaches at its mouth.

The resultants of the natural forces at work upon the inlet and lower reaches of North River, seem to determine toward a lessening of their depth and a shifting of the inlet southward. The results of Mr. Mitchell's survey show the capacity of the inlet and lower channel to be insufficient for the passage of a vessel suitable in size for the general purposes of freight or traffic. The inlet, as a harbor of refuge, is of no value.

While the bar at the mouth of the river has increased, and shoals have arisen within the channel above it, the extent and level of the marshes of the general valley remain unchanged and unobstructed. The plane of these marshes is below the range of spring

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and high storm tides which continue to overflow the entire valley, while the escape of the surplus water is retarded, and in a measure locked in by the high shoals and bar at the river's mouth.

These occasional excessive floods of salt water are injurious, in their effect upon the grasses of the marsh. It is a natural condition to all extensive tracts of salt marsh, that the margin of the main streams and tributaries, from their more ready drainage, become firmer and even higher ground than the rearward portions, which cannot cast off their surface waters quickly. The result is, that stronger grasses and firmer roots take hold of the best drained sections, which tends still more to keep back the ebbing water, so that in portions of marsh remote from the main streams, the grasses are sometimes entirely killed out by the long standing and stagnant water.

The salt marshes of North River are no exception to this general law, and left to the natural action of the tide will probably never much improve.

This last stated fact answers in part the second proposition: "Is the inlet and river likely to improve by natural causes and effects?" The negative seems the logical answer.

As before remarked, the inlet is evidently working southward, leaving a longer and shoaler channel between the main water basin and expanse of marsh, and the opening at the beach. This increased length of strait diminishes the power and action of the upper sections as a reservoir, when filled, and tends to lessen the probabilities of the natural deepening of the river or the bar.

In considering the third point proposed, the same conditions, influences and effects, bear on the question of artificial operations, which obtain in regard to natural ones.

Already the experiment of an artificial "cut" or opening, through the beach, as an improved mouth for the river, has been tried and has failed.

The excavation of a channel through the shoals of the lower reaches of the river would be attended with vast expense in proportion to the result obtained, and when done, the whole work might be destroyed by the action of a single storm in breaking over the lower portion of the outside beach and sanding up again, and changing the whole physical condition of the outlet of the river.

But should the artificial improvement of the mouth and channel of the river fully succeed, what would it effect?

When ship building and commerce occupied the borders of North River, no railroads or telegraphs controlled the business markets of the country, and the vessels built were of different style

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and different size from those of the present day. While it is true that a class of small vessels, such as coasting schooners, &c., might again be built upon the shores of North River, should its navigation be made sufficient for importing the necessary timber, and afterward, for launching the vessels and getting them out at sea, it is equally true that there are many harbors, rivers and waters in Massachusetts now unoccupied, which are more suitable for this business and purpose in their present natural state, than North River would or could be after the greatest improvement practicable.

Any large expenditure of money for the purpose of establishing maritime commerce only, could scarcely be made to pay, and would probably never become of material value to the community settled upon the shores of this small river.

We come, therefore, without a positive result in answer to the preceding questions, to the consideration of the fourth or last point proposed.

I submit that the first part of this question is answered by the results of Mr. Mitchell's observations and physical survey as stated in his interesting and valuable report. These have been confirmed by the study and formula applied by Mr. Clemens Herschel, who has been called upon to give his professional attention to the subject of the drainage of the river, and the construction of a dike and sluice-gates.

It is therefore demonstrated that it is practicable to shut out the tide-water, and to drain the river and the marshes successfully. The feasibility and value of the undertaking alone remain to be considered.

I will not here discuss the question of the result of drainage on the productiveness of these particular marshes. The result in the case of other salt marshes in no way differing from them in character or condition, is a matter of fact too well established to call for a reference even in this Report.

I am not able at this writing to refer to the soil of the marshes of North River, but I have before me specimens of the marsh compound of Green River, but a few miles below, and belonging to the same general coast formation.

Without attempting a scientific or chemical analysis of this material, I will state its general character.

At the surface of this marsh there is a mixture of fine gray sand and mud, with considerable fibrous woody matter. At one foot below the surface the material is similar, with a slightly larger proportion of mud and fibrous roots. At two feet below the surface but little sand, with masses of fibrous roots and mud. At three

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feet below the surface a similar compound to the last, with a larger proportion of mud. At four feet below the surface the character of the soil changes, and we find a fine yellow sand with some yellowish mud intermixed.

We have, therefore, the indication of a soil between three and four feet deep, of the richest character, abounding in fibrous vegetable matter and rich soluble earths.

The result of my survey determines an area of these marshes, including the mud flats of the water spaces, which amount to 3,074 acres.

Geographically, this territory is unlike many tracts of salt marsh bordering the main sea-board, which are generally in masses of large lateral extent.

The marsh bed of North River conforms to the general pathway of the stream, and occupies a tract immediately back of the outside beach for a distance of about five miles northward from the mouth of the river. At this point the river bends and trends westward and inland from the shore by a long and narrow valley, which varies in width from about 3,000 to 2,000 feet. In the central part of the valley the average width, for a short distance, is not over 600 or 700 feet. The total length of this tract of marsh above the site of the proposed dike and sluice-gates, and following the general course of the valley and its main branches, is about ten miles. The length of river, following its windings through the marsh from its mouth to the head of its tide-water at North River Bridge in the town of Hanover, is about fifteen miles.

The small lateral extent of the marshes in the upper portions of the valley makes them particularly well adapted to successful and profitable reclamation. The bed and channel of the river becomes a "*main drain*" into which the lateral drains can discharge their surplus waters advantageously.

The course of the river and valley is also of much favor to the community through which it passes, as it winds its way by almost every farmer's door and grounds, giving to the man of few as well as many acres the benefit of its improvement.

The early settlement of this section of the Commonwealth and the constant drain upon the natural resources of the soil have rendered the uplands in this neighborhood hard to till and of scant profit in their culture. There is, perhaps, no community where an acquisition of new, rich and easily cultivated land would be more acceptable than to the inhabitants of the borders of North River.

The already existing branch railroad to Hanover and the contemplated extension of the Cohasset Railroad to Duxbury passing across

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the lower part of these marshes will afford unusual facilities for transporting surplus produce to Boston and other markets.

I leave the statistics and discussion of the relative values of such marshes as those under consideration, in an unreclaimed or reclaimed condition. Allusion has been made by Mr. Mitchell, in his report, to the New Jersey and other marshes. Cases abound which prove the value and advantage of such improvement as is now proposed. There seems to be no question, in the case of North River, of the feasibility and desirability of reclaiming its valley by the drainage scheme proposed. And no question between the value of the river for maritime commerce and ship building, and that of the improved marshes as an agricultural district, which must far exceed in value any other use to which they can be put.

Green Harbor River.

In addition to the survey of North River, Mr. Tittmann executed, under my general charge, a survey of the upper part of Green Harbor River, from the limits of the former field work of the Coast Survey by Assistant A. M. Harrison, to the head of the Green Harbor River marshes.

This survey covers the ground included in the scheme of drainage proposed for Green Harbor River, and gives the same data for the details of this work as that furnished by the maps of North River. It also gives the full area of the Green Harbor River marshes which amount to about 1,506 acres.

The physical condition of Green Harbor River and the relation of the marshes to it offer a more simple problem for successful drainage than that offered by North River. The report of Prof. Mitchell fully presents the subjects of the drainage of each of these rivers.

The commerce of Green Harbor River is but of limited amount and of small value, and what there is, seems mostly confined to the lower part of the river. The site of the proposed dike and sluice-gates is above the location of the wharves and landings now in use, so that the portion of the river cut off and appropriated to the purposes of drainage and agriculture will not materially affect its commercial uses.

The navigability of Green Harbor River as affected by its change of physical condition from an open tide-water stream to one closed not far above its mouth by a dike and sluice-gates, is a question of some uncertainty.

The mouth of Green Harbor River differs from that of North River in its local condition and surroundings. The slight indenture in the general shore line and the shoal grounds of Brant Rocks and

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High Pine Ledge form a degree of shelter in the approaches and entrance to the river. As a small local harbor it also has some character. Once within the mouth of the river a small vessel would find good anchorage, a sufficient depth of water and complete shelter. The entrance, however, is shoaler than the river within and really cannot be called navigable at low water.

Considered as a commercial port the whole available water is but of small extent.

As a harbor of refuge it will probably never be of use except by local fishing boats and small pleasure yachts of the immediate neighborhood. For coasting vessels generally, or any craft seeking a harbor of refuge merely, the far more accessible and ample harbor inside the Gurnet, but a few miles southward, renders Green Harbor River of no value as a public refuge.

It is questionable whether the construction of a dike and gates, by shutting off the upper reaches of the marsh creeks as a reservoir, will materially affect the river below them, or injure the entrance to it.

But even if this should be the case, at some remote day, the reclaimed marshes will be of far greater value to the local community, and to the town, county and State, as an agricultural district, than any use which can be made of the unimproved waters of the river.

Respectfully submitted.

HENRY L. WHITING,
Chief of Topography of United States Coast Survey.

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REPORT OF GENERAL FOSTER.

BOSTON, MASS., January 16, 1871.

HON. JOSIAH QUINCY, *Chairman of Board of Harbor Commissioners:*

SIR,—I have the honor to furnish you with a copy of my report on Boston Harbor, by permission of the Chief Engineer of the army.

Very respectfully, your obedient servant,

J. G. FOSTER,
Brevet Major-General U. S. A.

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BOSTON, MASS., January 10, 1871.

Brigadier-General A. A. HUMPHREYS, *Chief of Engineers U. S. A., Washington, D. C.:*

GENERAL,—As the operations of the year, upon the works of improvement in this harbor, have closed, and as the greater portion of the work accomplished was done during the latter part of the season, and consequently not included in my report at the close of the fiscal year, June 30, it seems to be a proper and favorable time for presenting a comprehensive report of the whole season's work; and also, being of interest in the connection, to give a brief sketch of the plans adopted for the preservation and improvement of the harbor, the progress thus far made in their execution, the results and ascertained facts, and the proper conclusions to be drawn from them.

The natural boundaries of Boston Harbor include all the expanse of tide-water lying within a line drawn from Point Allerton to Point Shirley, and extending from that line westward to the shores of the main land.

This comprises a surface area of nearly thirty-one thousand acres, from which, deducting the area of the islands within the harbor, nearly one thousand acres in extent, gives a water area of the harbor of twenty-nine thousand seven hundred acres. This large expanse is well sheltered from the ocean by Point Allerton and the ten seaward islands, among which the most important are Deer Island, Lovell's Island, and the three Brewster Islands. These islands and the adjacent headlands constitute the natural breakwaters of the harbor, through which the two deep channels—the Main Ship Channel and Broad Sound Channel—pass in such a manner, that all vessels, as soon as they are fairly within the portals of the harbor, are within easy access of well-sheltered roadsteads.

The large interior basin of the harbor is fortunately divided into many excellent anchorages, both for light and heavy draught vessels, by the favorable position of the numerous islands in the harbor. Of the eighteen of these that appear on the chart, the most important in respect to the protection they afford to shipping, are George's Island, Gallop's Island, Long Island, Peddock's Island, Castle and Governor's Islands.

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George's Island shelters the shipping in George's Roads from the easterly gales, and also a part of Nantasket Roads from northerly winds. Gallop's Island also affords protection to George's Roads on the north, and to the Main Ship Channel on the west and south-west.

Long Island shelters the President's Roads from the south and south-east storms and George's Roads from the north-west and westerly gales. Peddock's Island protects Hull Basin on the north-west and a large portion of Nantasket Roads on the south. Castle and Governor's Islands afford protection to the "Upper Harbor," as the portion of the harbor lying west of Fort Independence is usually termed, in contradistinction to the "Lower Harbor," which comprises all the water surface extending eastward to the entrances.

The first class anchorages, sheltered by the above islands, for vessels of twenty-three feet draught, at all stages of the tide, are as follows:—

Nantasket Roads, containing	1,720	acres.
Hull Basin, containing	730	"
George's Roads, containing	490	"
President's Roads, containing	1,010	"
Upper Harbor, containing	200	"
Total,	4,150	"

The above does not include the areas of the Main Ship Channel, nor the anchorages north of the Lower Middle Ground. It does include the area of the Upper Harbor, because it is now connected with the deep water of the Lower Harbor, a cut having been made by dredging, during the past season, entirely through the Upper Middle Bar, to a depth of over twenty-three feet at mean low water. This cut, now only forty-five feet in width, it is proposed to widen, during the next and following seasons, to three hundred feet; or more, if navigation shall require it.

Nearly all the islands of the harbor are now entirely destitute of trees. A few remain upon Apple Island, and a small number have been planted on George's Island by the Government since the construction of Fort Warren. Yet history and tradition both agree in stating, that at the time of the first explorations by the Pilgrims nearly all the islands were well wooded. Some of them bore evidences of having been inhabited and cleared for cultivation. The new work by Hon. N. B. Shurtleff, entitled "Topographical and Historical Description of Boston," contains many interesting

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extracts from old records, showing the impressions made upon the first explorers by the natural advantages of the harbor.

One writer in 1634, says:—

"It is a safe and pleasant Harbour within, having but one common and safe entrance, and that not very broad, there scarce being room for 3 ships to come in board and board at a time; but being once within, there is anchorage for 500 ships. This Harbour is made by a great company of Ilands, whose high cliffs shoulder out the boistrous Seas, yet may easily deceive any unskilful Pilots; presenting many faire openings and broad sounds, which afford too shallow water for any Ships, though navigable for boates and small pinnaces.

"The entrance into the great Haven is called *Nantascot;* this place of itself is a very good Haven, where ships commonly cast anchor, until winde and tyde serve them for other places; from hence they may sayle to the River of *Wessaguscus*, *Neponset*, *Charles River* and *Misticke River*, on which Rivers bee seated many Townes. In any of these fore-named harbours, the seamen having spent their old store of Wood and Water, may have fresh supplies from the adjacent Ilands, with good timber to repair their weather-beaten Ships; Here likewise may be had masts or yards; being store of such Trees as are useful for the same purpose."

The same writer in 1635, says:—

"These Isles abound with woods, and water, and meadow grounds, and whatever the spacious fertile maine affords," &c.

It is not remarkable that the great value of the harbor, and the protection afforded to the anchorage grounds by the numerous islands, should have strongly impressed the early explorers. Its natural advantages, strongly impress at the present time, all those who carefully study its physical characteristics.

Professor Henry Mitchell, in a recent unpublished report, says:—

"The great merit of Boston Harbor lies in a happy conjunction of many favorable elements, among which we may distinguish, as most important, the facility and safety of its approaches, the ample width and depth of its entrances, and, above all, the shelter and tranquillity of its roadsteads. Perhaps there is no other harbor in the world where the inlets from the ocean are better adjusted to the amplitude of the interior basins, and whose excellent holding grounds are so easy of access and yet so land-locked. I quote from the highest authority in my profession when I declare that the primary requisite for a good harbor is that '*The internal area should bear such a relation to the width of entrance as to produce a sufficient degree of tranquillity,*'*

* Stevenson on Harbors.

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and so difficult has it been to properly adjust this relation, in artificial harbors, that nearly one-half of all these works may be set down as failures, because the entrances are either too narrow to admit vessels under trying circumstances, or the interior reservoirs too small to dissipate the waves that run in from the sea.

"In natural harbors where the primary requisite, cited above, is fulfilled, it often happens that the interior basin is so large that the local effects of strong winds are sources of discomfort and even danger—as in San Francisco.

"Boston Harbor has no such drawbacks; her interior water space is large, but is divided by chains of islands into basins, which offer sufficient room for the heaviest ships to ride freely at anchor, and sufficient tranquillity for the frailest fishing boat."

It does not appear, however, that the early settlers, properly appreciated the value of the *trees* upon the islands, as affording additional shelter to the anchorage grounds, or protection for the islands themselves against the assaults of the winds and waves. The old records are interspersed with permits and votes of towns, authorizing the cutting off the trees and wood upon the islands. The destruction of this natural protection appears to have rapidly progressed. This was a serious loss to the roadsteads, as it deprived vessels of one-half the shelter afforded from the winds by the islands.

To illustrate the estimate that would be placed upon the loss of such protection, in the present era of large ships with lofty masts and heavy spars, I again quote Professor Mitchell, in saying,—

"There are times when shelter from the wind is scarcely less important than smooth water. In the harbor of Cherbourg, the inrun of the waves is most effectually arrested by the great mole, and yet nearly every vessel that sought its shelter in the gale of 1865, was driven on shore by the wind.

"Here, again, Boston Harbor claims peculiar advantages. Her moles are promontories and islands rising from twenty to one hundred feet above the sea, so as to shelter the hull of a ship and much of her top-hamper."

The extent of the loss to the *islands themselves*, may be estimated from the amount of the resulting injury. Their sides being left exposed to the full force of the winds and their shores to the cutting and dissolving action of the waves, intensified by the lower sweep of the winds, were subjected to gradual destruction.

The effect of the waves in storms, dashing against the exposed shores, is evident to any observer: portions of the material of the formation are dislodged by every dash of the waves; the lighter particles being borne back by the receding waves or undertow, are

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either deposited at once in front of the abraded bluff, or are carried away by the currents to other points where, becoming checked in motion, they are deposited to form bars or shoals encroaching upon the roadsteads or channels.

The portions of the material, too heavy to be borne by the currents, are sometimes *driven* by the force of the waves, along the shore, until the moving forces cease or are neutralized.

As the lighter material is washed away, the boulders fall out, and rolling down to the foot of the bank, remain there, forming in time an apron of stone, to serve as a protection against further encroachments. Thus the very process of destruction produces, in time, a protection against itself.

But the removal of these water-worn and rounded stones to serve as ballast or paving-stones (which was prohibited by law on Bird Island, in June, 1818, but not prohibited on the other islands until June 6, 1856), necessarily exposed more of the bank to be washed down, until a new crop of stone was produced.

Whatever the precise character of the *causes* of destruction may have been, the *results* soon became so apparent as to attract public attention, and to alarm those interested in the preservation of the harbor.

Some islands were found to have been entirely washed away, leaving dangerous shoals in their places. *Ram's Head*, a small island situated 550 yards north-east of the north head of Lovell's Island, and containing several acres, had entirely disappeared, leaving one of the most dangerous shoals at the Broad Sound entrance. Upon this shoal, about forty years ago, the Maine Packet was wrecked, and all the passengers, fifteen in number, perished of exposure and cold.

Nix's Mate, once a considerable island according to the old colony records, which show, that on the 8th of September, 1636, "There is twelve acres of land granted to John Galop, upon Nixes Island, to enjoy to him and his heirs forever, if the iland bee so much." Des Barre's Chart of the survey of 1769 shows Nix's Mate to have been, at that time, an island containing about six acres. This island was long since washed away, leaving in its place a shoal, in close proximity to the main channel, upon which many vessels, each year, run aground.

Bird Island shoal, in the upper harbor, was once an island, and inhabited in 1634.

This washing away of the islands and headlands early called attention to the necessity of the preservation of what remained, and for this purpose the aid of the general government was invoked.

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In the year 1825, upon the petition of the city of Boston, and by the exertions of the senators and representatives in congress, an appropriation of $40,000 was obtained for the protection of Deer and George's Islands,—which was, however, exhausted in protecting George's Island.

In 1828 an appropriation of $87,000 was obtained for the construction of a sea-wall for the protection of Deer Island; and a dry stone wall was built on the east side of the island, in three sections, covering the three prominent headlands. Subsequent appropriations for the repairs and rebuilding of this wall were made by congress.

In 1843 an appropriation of $15,000 was obtained, and expended by Colonel Sylvanus Thayer in the construction of a sea-wall on the north head of Lovell's Island.

Other appropriations were subsequently made for this island and Great Brewster Island, on each of which substantial and costly sea-walls have been built and maintained by the general government.

These islands, being the larger of the seaward islands, were the first to receive the attention of the government in the way of protection.

But the islands lying more westerly in the harbor were justly regarded as also requiring protection, being important as the more immediate shelters for the safest and best anchorages.

At the request of the City of Boston, the general government, in 1860, appointed a board of commissioners to examine Boston Harbor. This board consisted of General J. G. Totten, Chief Engineer U. S. A.; Professor A. D. Bache, Superintendent U. S. Coast Survey; and Commander C. H. Davis, U. S. Navy.

Under the direction of this board, but at the expense of the city of Boston, extensive hydrographical and physical surveys of the channels and shoals, and topographical surveys of the shores of the islands, were made by Coast Survey officers.

From these surveys were prepared elaborate and detailed maps and tables of results, clearly showing the injurious changes that had taken place, and indicating the measures necessary to be taken to check them.

These surveys and results were from time to time, from 1860 to 1866, communicated to the city government of Boston in carefully prepared and elaborate reports. In these reports the commissioners strongly urged the construction of sea-walls for the preservation of the prominent headlands of the harbor, using, in the second report, the following strong language to express their convictions:—

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"First, that injurious changes are going on unceasingly; and second, that the time is approaching when those who are responsible for the preservation of Boston Harbor must make up their minds either to abandon the lower harbor to its fate or to make immediate application of the remedy—and the only remedy—by which the progress of these injuries can be arrested. This remedy is manifestly the continuation of the old and the construction of new sea-walls; a proper grading of the hills, and a planting of a suitable grass or shrub on the unsheltered surfaces."

Professor Henry L. Whiting of the U. S. Coast Survey, who made the above topographical surveys, arrived at some interesting conclusions as to the probable original extent of the prominent headlands and islands, by completing the contour curves in a manner analogous to the curves of existing hills in the neighborhood. According to his estimates, the "Little Hill" of Point Allerton originally extended to beyond the present position of the beacon, and was about one hundred feet high. It was at the date of the survey reduced in height to sixty feet, and had lost, by washing away, nearly forty-three acres. The loss in thirteen years—from 1847 to 1860—had been twenty-two thousand square feet. The loss of the "Great Hill" of Point Allerton had been in thirteen years—from 1847 to 1860—forty thousand square feet. The Great Brewster Island had lost over thirty-two acres, the encroachments extending to the summit of the largest hill. Two hundred and twenty thousand square feet had been washed away in the thirteen years preceding 1860. Deer, Lovell's, Gallop's, Long, and the other islands, had all lost by washing away in a similar manner, but many of them in a less proportion.

The Board of Harbor Commissioners, organized by the legislature of Massachusetts in 1866, took up the matter with active interest, and caused carefully prepared plans and estimates to be made of the cost of sea-walls, and of deepening and widening the main ship channel by dredging, and the removal by blasting of dangerous rocks lying in the channel. These plans and estimates were forwarded, with a petition to congress, to the chief of engineers (yourself), by whom those for the most important objects, viz.: sea-wall for Point Allerton, Gallop's Island and North Head of Long Island, dredging off the south-west point of Lovell's Island, the west extremity of the Great Brewster Spit, and the Upper Middle Bar, together with the removal of Tower and Corwin Rocks, were approved and recommended to the secretary of war, by whom they were also approved. By these approvals, and the exertions of the Harbor Commissioners and representation of the State in Congress,

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an appropriation was at once obtained from Congress of three hundred and seventy-five thousand dollars, three hundred thousand of which were for the new works estimated for, and approved by you, and which were placed in my charge.

In 1868 Congress further appropriated $33,000; in 1869, $83,000, and in 1870, $100,000 more, making in all, in four years, the amount of $516,000 for these new works.

The *Progress* made up to the present time in these several works, in my charge, is as follows:—

Removal of the Rocks in the Channels.

In 1867 operations in drilling and blasting "Tower Rock," situated one hundred yards south-west from the Great Brewster Spit Light, resulted, after a few months of successful work, in its reduction to a depth of twenty-three feet, at mean low water. Operations were then commenced on "Corwin Rock," situated one hundred yards south-west of Tower Rock. This being a much larger rock, work was continued during the whole season of 1868, and again in the summer of 1869; in the month of June of which year its entire removal to the depth of twenty-three feet at low water was accomplished. Operations were then commenced on "Barrel Rock," a boulder lying in Broad Sound, about one mile a little north of west from Green Island, and near the sailing line of the Portland and other Maine steamers. Having only four feet of water upon it at low tide, it constituted, in thick weather, a dangerous obstacle to navigation. It was successfully blasted, and the fragments were all removed to the shore or into deep water.

Operations were then commenced on "Kelly's Ledge," a rock with sixteen feet of water upon it, lying in the main ship channel, directly in the line from the entrance buoy to the Spit Light. Heavy draught vessels being obliged to pass either to the right or left of this rock, necessarily incurred considerable danger, in foggy weather, from the proximity of the extensive "Centurion Rocks" on one side, and of the Beacon Rocks, near the edge of Brewster Spit, on the other. The season closed when about one-half the work on this rock was completed. It was resumed the past season and diligently prosecuted; but owing to the very unfavorable character of the rock, being a soft slate, with contorted laminations, filled with crystals of sulphuret of iron (iron pyrites), which impeded the action of the drill, the progress of the work was necessarily very slow. The heaviest charges of powder and other explosives used, failed to produce much effect upon the soft rock.

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The work was stopped on the 30th of December on account of the weather, and before three high points, left by the blasts, had been reduced to the required level of twenty-three feet at low water, although the general surface was below that level.

These points have now twenty-one and a half feet of water at low tide upon them, and can easily, in a few days of favorable weather, be blasted down to the requisite level. The removal of this rock secures a great advantage to navigators in enabling them to make one straight course from the entrance buoy to the Spit Light.

The Great Brewster Spit.

No attempt has yet been made to cut off by dredging, the west extremity of this spit; because, during the removal of Tower Rock, the divers observed and reported, that the rock rose in a gradual ascent towards it and evidently formed the backbone of the spit, the projection or ridges being outcroppings of the general ledge of rock underlying this part of the harbor, running in a north-east and south-west direction, and forming the foundation of the seaward islands "whose high cliffs shoulder out the boistrous seas."

The deposits at the end of the spit have not, as yet, reached such deep water as to render their removal by dredging absolutely necessary. Its present growth, as reported by the light-keeper, is towards the west and south, and has been quite rapid within a few years. The supply of material for its growth appears not yet to be entirely cut off by the completion of the Great Brewster Sea-wall. The angle of that wall, on the east side, near the large hill, being very near the bluff, appears to permit the waves,—when they have gathered force by being compressed in the re-entering angle,—to mount the wall and dislodge large masses of the steep bank. This will probably continue until all the earth that can be reached by the breaking waves is washed away; or until the bluff is graded into a slope suitable to resist the action of the seas.

I do not therefore think it advisable to expend anything, at present, in dredging the extremity of the spit, but to await the ultimation of the effects of the causes still remaining in force.

Widening the Main Ship Channel by Dredging off the South-west Point of Lovell's Island.

This work was commenced in 1868, and continued in 1869; the whole point was cut off for a width, in a direction perpendicular to the axis of the channel, of two hundred and sixty feet, from the top of the bank, in a regular slope, to the depth of twenty-three feet at low water. This has caused a slight increase of the ebb

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scour through the Narrows, which has appreciably enlarged the widening, and smoothed off all projecting ridges left in the hard bottom by the buckets of the dredges.

This improvement has widened the channel at this point, at the depth of the eighteen feet curve, from its former width of three hundred and sixty-five feet, to six hundred and twenty-five feet, a gain of two hundred and sixty feet.

Nothing more, in my opinion need be done at this point of Lovell's Island; but I propose to dredge off the extremity of a shoal making out from the east side of Gallop's Island, on the opposite side of the channel. Upon this spit, called Cape Cod Shoal, many vessels get aground at low water, and it is a much needed improvement to dredge off its point in a line parallel to the axis of the channel, so as to make the channel as wide at this point as it now is at other places.

Dredging a Channel through the Upper Middle Bar.

The peculiar character of the material of this bar—a very hard, indurated yellow clay (hard pan),—prevented the different machines that were successively tried during the three past seasons, from succeeding. During this season, however, Mr. E. A. Seward of Albany, the contractor, with the assistance of Mr. C. H. Montine as subcontrator, has succeeded in making one straight cut, two thousand two hundred feet in length, entirely through the bar, to a depth of twenty-three feet at low water, and a width of sixty feet. This cut is marked by three spar buoys. Eighteen thousand six hundred cubic yards of material have been dredged and dumped during the season. The widening of this cut will be continued during the next season, in which it is expected a width of three hundred feet will be obtained.

Sea- Wall at Gallop's Island.

The construction of a wall for the protection of the north and east sides of this island was commenced in 1868, and continued in 1869 and 1870. The wall proper was completed about the middle of October last. The earth backing has been filled in for about two-thirds the length of the wall, and its west end has been connected with the bank by a short dry wall, with an apron of stone in front. The stone for the flagging to be placed back of the coping course, is on hand, ready to be laid during the coming season. The character of this wall is shown in the accompanying sketch. It has a strong granite facing of headers and stretchers, with dovetailed joints, and a compact concrete backing. Its height varies from

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fourteen to seventeen feet (having an extra course at the bottom for a portion of its length). Its thickness is nine feet at bottom, and five feet at top. Its foundation is a compact mass of concrete three feet thick, and thirteen and a half feet wide. This foundation is laid in a trench excavated to an extremely compact stratum of gravel and clay, or hard pan. It is located nearly on the line of ordinary high water. The total length of the wall is 1,745 running feet.

The appropriation called for in the annual report of June 30th, 1870, is much needed to complete, in the next season, the back filling of earth, to lay the granite flagging back of the coping, and to slope down and grass the steep face of the bluff.

Construction of Sea-Wall at the North Head of Long Island.

Operations were commenced by the contractor, Mr. James Andrews, about the middle of August last, and continued during the season. A wharf for landing materials was constructed by him at the north-west point of the head, from which a railroad track was laid to the location of the wall. A cement-house was built by me, and quarters for his men were erected by the contractor. During the season the foundation course for five hundred and twenty-four feet in length of the wall was built, and three courses above the foundation laid, to nearly the same extent. A large amount of material is on hand ready for the next season's work. This wall is to be of a character similar to that of the Gallop's Island sea-wall. Its cross section is seen in the accompanying sketch.

Sea-Wall for the Preservation of Point Allerton.

This exposed and rapidly disappearing headland should, from its important character, have been protected at the earliest possible day; but, owing to the numerous delays in obtaining a deed of the site, and the privilege of locating in a safe place the wharf for landing materials, the work of construction was not commenced until this season.

A wharf four hundred and seventy feet in length, extending to the channel, was built on the south and sheltered side of Stony Beach, and a cement-house was erected near by. A railroad track for conveyance of materials was laid by the contractor, Mr. James M. Andrews, from the wharf to the site of the sea-wall, a distance of four thousand two hundred feet. Quarters for his men, and sheds for material and tools, were erected by the contractor.

These preliminary labors occupied so much time that the first pit for the foundation was not started till the last of September, and the work continued only till the first of December. In this

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time three hundred and twenty-two feet of foundation, and of the two first courses of the wall, were laid, and backed with concrete and earth.

This wall is similar in character to the Gallop's Island sea-wall, but is made stronger and higher on account of its exposed situation. Its cross section is seen in the accompanying sketch. It is located nearly on the high-water line, and its foundation is placed at a greater depth and upon the same kind of "hard pan" substratum as that obtained for the other sea-walls. It is to be of sufficient length to inclose the face of what remains of "Little Hill." The appropriation asked for will complete the wall proper in the coming season. It is hoped that these timely preservative means to save the remains of "Little Hill" may also arrest the washing away of "Great Hill."

Point Allerton, one of the most marked and prominent headlands that meet the eye of the mariner in approaching the harbor, will thus be preserved nearly in its present distinctive characteristics. The only alterations will be in the features of "Little Hill," and will consist of the substitution of the profile of the sea-wall, terminating in a graded and grassed slope for the present sharp outline and seamed face.

It appears from the directions on the Coast Survey chart, under the head of ranges, that this headland is a useful guide for avoiding the dangers of Harding's Ledge when passing to the southward of it in entering or leaving the harbor.

"Point Allerton Bluff," says Professor Mitchell in his recent letter to the Harbor Commissioners, "remembered first and foremost in your prayers to Congress, is the *pier-head* of the natural mole that defends the lower roadsteads. If it were suffered to waste away the Hull basin would be utterly ruined; and as the opening of the harbor widened, the other anchorage grounds would become unsafe.

"Within the past thirty-eight years the French government has expended some *eight and a half million of francs* for the shore protections of the neck of land which forms the *leeward* point of the embouchure of the Gironde. The reasons assigned for this expenditure were that the point, by falling back, threatened to expose the roadstead of Verdon, and that the pass into the ocean would diminish in depth if suffered to expand."

Comparison of Surveys.

In seeking to ascertain where the materials washed away from this point have been carried, and if any have been deposited in the

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main channel, I caused a careful comparison of all the surveys from 1769 to the present time to be made.

The results of this comparison, exhibited in the comparative map accompanying my letter of April 13, 1870, show that within the limits covered by the comparative map, extending about 2,000 feet outside of the entrance and 5,000 feet within, covering an area of the main channel of 451 acres, there has been a shoaling to the extent of nearly *five millions of cubic yards of material.* Were this immense quantity spread out over Boston Common it would cover it to the depth of *sixty-four feet.*

This great deposit did not, probably, all come from Point Allerton; in fact, its source can only be ascertained positively by an accurate and minute geological survey, as recommended by Professor Agassiz in his letter of September 11, 1867, published in the Coast Survey report for that year.

But the movement of the curves of depth outwardly towards the channel is a strong indication that most of the shoaling came from the point.

This outward movement is very decided in the twelve, eighteen and twenty-four feet curves, the latter curve having moved out about *one thousand feet.* The deeper curves have moved less; some of the deepest ones have, however, been entirely obliterated, as for instance the forty-eight and fifty-four feet curves shown on Wadsworth's map of 1817 about half-way between Point Allerton and Boston Light, which are entirely wanting on the Commissioners' map of 1863. The importance of the construction of a sea-wall to preserve Point Allerton, and to shut off this source of supply of material for the shoaling, is thus rendered clearly manifest.

Conclusion.

During the few years that I have had charge of the works of preservation and improvement of the harbor, I have had the advantage of being intimately associated with the Board of Harbor Commissioners of Massachusetts, and Professors Mitchell and Whiting of the Coast Survey, both of whom have been connected with this subject from the first surveys of the United States commissioners to the present time, and are thoroughly acquainted with the details and scope of the original plans.

The *general principles*, as I understand, which guided the United States commissioners in their original investigations and reports upon Boston Harbor, and which likewise actuated the Harbor Commissioners of the State in their exertions and petitions for national aid, were those of *preservation* and *compensation;* and aimed *first* "to preserve

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the great physical features in their ancient order, and to hold on to the old landmarks"; and *secondly*, to compensate, as far as possible, for the evils already caused by a neglect of the above principle, by widening, deepening, and removing obstructions from the main channels.

Their reasons for preserving the prominent headlands and islands were threefold: first, because of their value as *shelters* to the anchorage grounds; second, because if washed away, much of their material *must be deposited somewhere in the roadsteads and channels;* and third, because "as these bluffs fall back they *leave in their places dangerous shoals and reefs*, hidden for the most part, especially at high tide, and these embarrass the navigator, even when he is familiar with their existence and whereabouts."

My own observations and investigations have confirmed my first impressions of the wisdom of the views thus originally entertained; and have convinced me that the carrying out of the proposed plans,—at least, to the extent of the prompt completion of such of the proposed works as have received your endorsement and are now in progress,—is absolutely necessary for the preservation of this harbor, which is justly regarded as one of the most important upon the whole Atlantic coast.

I have the honor to be,
Very respectfully,
Your obedient servant,

J. G. FOSTER,
Lieutenant-Colonel Engineers.

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